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THESIS

AN ANALYSIS OF USING INTELLIGENT DIGITAL DATA TO REDUCE THE SPARE AND REPAIR PARTS INVENTORY FOR THE NEW ATTACK SUBMARINE (NSSN)

by

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Both the defense and commercial industry sectors are increasingly moving to automated manufacturing as a means to reduce costs and increase efficiency and quality. The Navy can leverage both the capabilities as well as the benefits of this technology application. For example, the acquisition of intelligent digital data in support of the new weapon systems has the potential to render a percentage of the Navy/DLA parts inventory as "virtual". This inventory would exist in "effect" but not in actual form until required. The Navy has developed and demonstrated the capability to use intelligent digital data to manufacture no-longer-available parts in a timely and cost-effective manner. The application of this technology is a natural complement to the advanced technology in computer-aided design and manufacturing incorporated in the Navy's newest weapon systems under procurement, specifically, the New Attack Submarine. This thesis presents an analysis of the application of this technology. There exists a market for this technology application as demonstrated by the intelligent digital data candidate parts analysis conducted during this investigation. As a result of this analysis it was determined that the Navy can conservatively save $503 million over the life cycle of the New Attack Submarine by the applying the use intelligent digital data.

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ABSTRACT

Both the defense and commercial industry sectors are increasingly moving to automated manufacturing as a means to reduce costs and increase efficiency and quality. The Navy can leverage both the capabilities as well as the benefits of this technology application. For example, the acquisition of intelligent digital data in support of the new weapon systems has the potential to render a percentage of the Navy/DLA parts inventory as "virtual". This inventory would exist in "effect" but not in actual form until required. The Navy has developed and demonstrated the capability to use intelligent digital data to manufacture no-longer-available parts in a timely and cost-effective manner. The application of this technology is a natural complement to the advanced technology in computer-aided design and manufacturing incorporated in the Navy's newest weapon systems under procurement, specifically, the New Attack Submarine. This thesis presents an analysis of the application of this technology. There exists a market for this technology application as demonstrated by the intelligent digital data candidate parts analysis conducted during this investigation. As a result of this analysis it was determined that the Navy can conservatively save $503 million over the life cycle of the New Attack Submarine by the applying the use intelligent digital data.

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I. INTRODUCTION

The acquisition of data in digital format offers numerous benefits to the department, most of which translate directly into cost savings.
(Longuemare, 1996)

Can the Navy apply intelligent digital data currently in use in the design and manufacture of its weapon systems to the reduction of the spare and repair parts inventory? More specifically, does the capability exist to do so? Is there a need to do so? Is the Navy interested in doing so? What are the costs involved in doing so? These are the questions this thesis investigates. The commercial sector is increasingly moving to automated manufacturing as a means to reduce costs and increase efficiency and quality. "Modern industrial production is increasingly characterized by manufacturing technologies that incorporate computer based automation and information systems." (McGraw-Hill, 1995) In the 1980s, United States manufacturers spent over $400 billion on automation equipment, technologies, and facilities (St. Charles, 1989). The relationship between technology and economics is characterized by the following statement:

> The speed and extent of recent advances reflect the timely interaction of computer technologies with economic realities. Giving customers a quality product with the features they want as soon as possible and at a competitive price is the engine driving many successful manufacturing endeavors. (McGraw-Hill, 1995)

The Department of Defense is one of those customers.

The Department of Defense has recently embraced the digital environment. The Department of Defense initiatives include the goal of "moving to a paper-free contracting process by January 1, 2000" (Hamre, 1997), and the "migration of acquisition and

logistics operations to digital methodologies and products by 2002." (Phillips, 1997) The Department of Defense's progression towards a digital environment is demonstrated by the series of initiatives contained in the memorandums included in Appendix A.

The Navy has demonstrated not only the ability to employ the concepts of computer-aided design (CAD), computer-aided manufacturing (CAM), and flexible manufacturing in the production and support of its weapon systems, but also the ability to capitalize on technology available or under development in the commercial sector to develop new weapon systems and maintain older weapon systems. For example, the New Attack Submarine Program is being developed with a state-of-the-art CAD/CAM application (Kowenhaven and Harris, 1997). Another example is the Navy's Rapid Acquisition of Manufactured Parts (RAMP) Program. RAMP has proven successful in the application of digital technology to the timely and cost-effective production of no-longer-manufactured parts which were historically known to have long lead times.

The Navy has embraced digital technology in other areas as well. The "paperless Navy" initiatives in message traffic distribution and publication maintenance are further examples. More complex examples include the computer networks established between Navy program offices and prime contractors to speed the flow of information and hopefully speed the development and production in the program. The Navy, however, has been slow to embrace digital data and use technology such as that found in RAMP as a means of assuring future affordable and responsive support to these same weapons systems.

Where in the vast Navy spare and repair parts inventory might such an application of technology be most beneficial? One such application may be the United States Submarine Force. The makeup of the Submarine Force has changed drastically over the past decade. The Submarine Force of FY-97 is composed of 73 Attack Submarines and 18 Fleet Ballistic Missile Submarines (Dalton, 1996). This total of 91 submarines is down from the Cold War high of 139 submarines in FY-87 (Chief of Naval Operations, 1994). *The Report of the Quadrennial Defense Review* recommended the further reduction in the attack submarine force to 50 submarines (Cohen, 1997). The last four major submarine classes have been relatively large sized: the LOS ANGELES Class (62 submarines); the TRIDENT Class (18 submarines); the STURGEON Class (37 submarines); and the BEN FRANKLIN Class (41 submarines). However, the follow-on classes of submarines will be smaller: SEAWOLF Class (3 submarines) and New Attack Submarine (NSSN)[1] Class (30 submarines). Additionally, Congress has mandated that the first four New Attack Submarines be prototypes, in order to develop competition and innovation (Polmar, 1996).

The spare parts inventory of the current Submarine Force has traditionally been designed to support the large ship classes of the Cold War Era. The shrinking size of ship classes and the need to squeeze more return out of every budget dollar calls for evaluating whether the application of technology can increase the efficiency of the current spare parts

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[1] The New Attack Submarine (NSSN) was originally called the *Centurion* in its early phases of concept development. The name was later changed to New Attack Submarine (NAS) when Congress directed development of the program following the cost overruns of the SEAWOLF Program. The acronym NAS was later changed to NSSN (New SSN) to avoid confusion with other "NAS" acronyms.

inventory management system. The uniqueness of submarine operations and the spatial constraints that the submarine environments impose have by their very nature stripped the management of onboard spares to those that are absolutely necessary. In the management of wholesale sparing, that part of the spare and repair parts inventory not carried on board but maintained at depots, for the submarine force lies the potential for innovation and savings.

This thesis investigates the costs of integrating the use of intelligent digital data into Navy Inventory management. It will attempt to identify the potential costs of this integration, including the cost of obtaining and maintaining the design data from the contractor for each part. In the absence of specific examples of costs, a net present value estimation model will be employed to estimate the value to the Navy of intelligent digital for parts with a variety of part-specific characteristic combinations.

The process as well as the cost of obtaining the necessary intelligent digital data for Computer Integrated Manufacturing (CIM) will be analyzed. In addition, analysis will be conducted to determine how much of the New Attack Submarine repair parts inventory is within CIM/RAMP capabilities.

Finally, the net present value estimates and the CIM/RAMP manufacturable analysis will be combined to obtain a conservative estimate of the potential cost savings for the application of intelligent digital data to the New Attack Submarine.

The scope of this analysis will be limited to the New Attack Submarine. The New Attack Submarine was chosen because it is, according to the Department of Defense's acquisition community, "the most sophisticated product" ever procured by the Department

of Defense. It is the first weapon system designed solely on computer. (Acquisition Reform Office, 1996) The New Attack Submarine is also a system very early in its development and could benefit from this analysis.

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II. BACKGROUND

This chapter provides the background of the elements which are the focus of this thesis: manufacturing in the intelligent digital data environment and technology in ship design and manufacture. The importance of standards in a technologically advanced environment is discussed first. Next, the levels of design data are described to provide the reader with a context to understand potential uses for the intelligent digital data. Finally, the last section describes the New Attack Submarine (NSSN) Program–the Navy's most technologically advanced shipbuilding project to date–and the Rapid Acquisition of Manufactured Parts (RAMP) Program--a technologically advanced program designed to improve weapon system support while reducing support costs.

A. DIGITAL DATA APPLICATION

The storage and manipulation of data on a computer system is referred to as digital data processing. The differences in the terms "digital data" and "intelligent digital data" are manifest in the capabilities contained within the data. "Digital data" refers to information that delineates information about some concept or describes an object. The term "intelligent digital data" refers to information that not only describes the object, but also describes the manufacturing process for that object. The discussion in this section focuses on "intelligent digital data".

1. Industry Trends

> The technical intensity of many manufacturing and service industries has increased dramatically at the same time that a revolution in production systems, both the human and technical elements, has redefined the standard of competitive organizational and managerial performance for most companies. (National Academy of Engineering, 1993)

The overall trend in industry today is toward technical intensity. Just-in-time manufacturing, lean manufacturing, agile manufacturing, flexible manufacturing systems, computer integrated manufacturing (CIM), computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE) are just some of the terms associated with this industrial technical intensity. The benefits that industry hopes to achieve with technical intensity are decreased costs, increased efficiency, and improved quality (McGraw-Hill, 1995).

2. Data Exchange

It is not enough in this complex, fast-paced, economic environment to be able to effectively employ computer systems internally in an organization. A key to competitiveness is the ability to exchange data electronically in the business environment. (ECIC, 1995)

The exchange of business data in the computer environment is referred to as Electronic Commerce (EC). Electronic Commerce is the paperless exchange of business information using Electronic Data Interchange (EDI), electronic mail (E-mail), computer bulletin boards, fax, electronic funds transfer (EFT), and other similar technologies (ECIC, 1995).

The specific application within EC of EDI is a focal point of this thesis. Electronic Data Interchange (EDI) is the computer-to-computer exchange of business information using a public standard. Public standards are the agreed upon data format for the exchange. Standards are absolutely vital for the exchange of digital information. Standardized digital information is just as understandable, interpretable and useful to the person or machine receiving it as it was to the person or machine from which it originated. (CALS, 1997) EDI is a central part of EC because it enables businesses to exchange business information electronically much faster and more cost efficiently and accurately than would be possible using paper-based systems (ECIC, 1995).

3. Initiatives and Applications

The military has long understood the usefulness of digital data. From the Defense Advanced Research Projects Agency's (DARPA) development of the Internet to the development of wireless high-speed communications to the creation of devices and systems to store voluminous amounts of data and information in confined spaces, the United States military has benefited tremendously from applications of digital technology. The Department of Defense has established a series of ongoing initiatives to ensure that the department continues to actively apply all of the benefits that digital data have to offer in a coordinated manner. These initiatives include Continuous Acquisition and Lifecycle Support (CALS), Electronic Commerce/Electronic Data Interchange (EC/EDI), and Logistic Business Systems (LBS). In July 1997 the offices undertaking these three initiatives were consolidated into the Life-Cycle Information Integration Office. The

consolidation of these initiatives was seen as necessary because "The increasing complexities and interdependencies of acquisition and logistics systems integration requires a dedicated synergistic effort to address issues of information integration, and shared data throughout the weapon system life cycle." (Phillips, 1997)

CALS is a Department of Defense strategy to accelerate the transition from paper-intensive non-integrated product development, design, manufacturing, and support processes to a highly automated, integrated mode of operation by developing (1) standards for data storage and exchange and (2) automated systems to store, manage, and distribute this information to many and varied users across an enterprise. The CALS initiative and its subsequent spinoffs have emphasized the need for standards for the exchange of product data.

The need for product data standardization is further emphasized by the many and varied purposes to which product data are applied during the life cycle of a weapon system. These purposes include manufacture, design update, supply support, maintenance, and disposal. These purposes may involve different computer systems in different organizations and in different geographic locations. Additionally, over time, computer system hardware and software will continue to advance. Clearly, in order to sustain such a support environment organizations need to be able to represent their product information in a common, computer-interpretable form that is required to remain complete and consistent when exchanged among different and evolving computer systems. To this end, various organizations concerned with the use of digital data have pushed for standards to be established on an international level in this area. This emphasis has

resulted in the development and approval of an international standard for the exchange of digital data. The standard is called the Standard for the Exchange of Product Model Data (STEP).

a. *Standard for the Exchange of Product Model Data (STEP)*

The Standard for the Exchange of Product Model Data (STEP) is an international standard for the computer-interpretable representation and exchange of product data. The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product, independent of any particular system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving. (SCRA, 1997) STEP offers manufacturers, designers, contractors and others the ability to more easily share three-dimensional product information among CAD/CAM/CAE systems. (IBM/Dassault, 1997).

STEP gained international approval in December 1994 by the International Standards Organization (ISO) and was designated ISO Standard 10303. The standard has already been embraced by the private sector, as evidenced by General Motors employment of STEP in its production processes beginning in May 1996. (CALS, 1996)

The development and subsequent approval by the ISO is the result of the efforts of a consortium of industry and government organizations working toward a common goal. This consortium is known as Product Data Exchange Using STEP (PDES).

b. Product Data Exchange Using STEP (PDES)

Product Data Exchange Using STEP (PDES) is composed of 25 major industrial companies and government agencies who represent more than $600 billion in annual revenue (CALS, 1996). PDES acts to ensure that the requirements of United States industry are incorporated into STEP. PDES is a voluntary activity coordinated by the National Institute of Standards and Technology (NIST). (SCRA, 1997)

B. DESIGN AND MANUFACTURE

In discussing design data and its propensity for use in digital form, the definition of design data and the various levels must be clearly understood. Design data not only take on several formats but also, within the context of the Department of Defense, three specific levels of detail. The military specifications for the different levels of detail in engineering drawings and associated data are found in DOD-D-1000B dated 28 October 1977, with Amendment 3, dated 13 May 1983. The levels are structured to provide a natural progression from concept inception to production. There are three levels of engineering drawings. The definitions of each level follow:

1.. Level I - Conceptual and Developmental Design

> Engineering drawings and associated lists prepared to this Level shall, as a minimum, disclose engineering design information sufficient to evaluate an engineering concept and may provide information sufficient to fabricate developmental hardware. Engineering drawings and associated lists prepared to this Level shall be legible and include those types most amenable to the mode of presentation. Layout drawings and combinations of types of engineering drawings may be used to convey the engineering

concept in such a manner the engineering information is understandable to cognizant Government engineers and scientists or enable fabrication by the design contractor of developmental hardware for test or experimentation. (DOD-D-1000B, 1977)

2. Level II - Production Prototype and Limited Production

Engineering drawings and associated lists prepared to this Level shall, as a minimum, disclose a design approach suitable to support the manufacture of a production prototype and limited production models. Engineering drawing types shall include, as applicable, parts list, detail and assembly drawings, interface control data, diagrams, performance characteristics, critical manufacturing limits, and details of new materials and processes. Special inspection and test requirements necessary to determine compliance with requirements for the item shall be defined on the engineering drawings or referenced to a document acceptable to the Government.
(DOD-D-1000B, 1977)

3. Level III - Production

Engineering drawings and associated lists prepared to this level shall provide engineering definition sufficiently complete to enable a competent manufacturer to produce and maintain quality control of item(s) to the degree that physical and performance characteristics interchangeable with those of the original design are obtained without resorting to additional product design effort, additional design data, or recourse to the original design activity. These engineering drawings shall: (a) reflect the end product, (b) provide the engineering data for the support of quantity production, and (c) in conjunction with other related preprocurement data shall provide the necessary data to permit competitive procurement of items substantially identical to the original item(s). Engineering drawings shall include details of unique processes, i.e., not published or generally available to industry, when essential to design and manufacture; performance ratings; dimensional and tolerance data; critical manufacturing assembly sequences; input and output characteristics; diagrams; mechanical and electrical connections; physical characteristics including form and finish; details of material identification; inspection, test and evaluation criteria; necessary calibration information; and quality control data.
(DOD-D-1000B, 1977)

It is clear from the above definitions that the term "design data" can be an ambiguous term. For the purposes of this thesis the term "design data" will be used to mean level III design data. Any use of the term "design data" for other than level III shall be qualified to specify either level I or level II.

Design or equipment data for ships and other weapons systems have traditionally been supplied to the Navy in hardcopy form as well as stored on microfiche or microfilm. The computer age has provided the capability of storing this data on a variety of computer storage media for the purposes of retrieval, update, correction, viewing, and reproduction. These capabilities then provide for many applications related to weapon system support.

C. NAVY APPLICATIONS OF THE TECHNOLOGY

1. The New Attack Submarine (NSSN) Program

The New Attack Submarine was developed as a less costly alternative to the SEAWOLF Submarine. The New Attack Submarine Program began at a time when the SEAWOLF Program was battling for its life. The SEAWOLF Submarine was designed to combat the Cold War threat as the follow-on to the LOS ANGELES Class fast attack submarine. The SEAWOLF Submarine, a new and much improved design from that of the LOS ANGELES Class, was to be the answer to the Soviet Submarine Fleet's progress in narrowing the gap between it and the United States Submarine Force's acoustic advantage. The SEAWOLF's significant design changes to improve tactical performance and sensor and weapon capabilities came with an expensive price tag. It was a price that

Congress was not willing to pay, especially after the breakup of the former Soviet Union. The SEAWOLF Program started as a 29-ship class. After the 1990 Department of Defense Major Warship and Threat Review, SEAWOLF production was cut from 29 to 12 ships. There was an attempt to cancel the program in 1992 after completing only the lead ship. The attempt resulted in the program being cut back to two ships, with a third hull later authorized in FY-96. One of the reasons the SEAWOLF Class was reestablished after the attempted cancellation was to sustain the nuclear shipbuilding industrial base between completion of the last LOS ANGELES Class submarine and the lead ship of the New Attack Submarine Class. As the class was pared down in size, the economies of scale began to evaporate and the price per platform increased substantially. The cost of the SEAWOLF Program was capped by Congress in 1994 at $4.76 billion for two units. (Philpott, 1997; GAO/NSIAD-94-201BR, 1994)

The New Attack Submarine was developed to "fill out" the force level of 50 submarines beyond the year 2000, which was the anticipated need under the planning guidance of the early 1990s. The New Attack Submarine Program is planned for 30 platforms (GAO/NSIAD-97-25, 1996). The design team at Electric Boat has stated, "The objective of the NSSN Program is to produce a multi-mission, easy-to-upgrade submarine with the acoustic performance of the SEAWOLF (SSN-21), an acquisition cost equal to or lower than the cost of an additional LOS ANGELES (SSN-688)-Class submarine, and low life cycle cost." (Kowenhaven and Harris, 1997)

In February 1991, the Secretary of the Navy (SECNAV) and Chief of Naval Operations (CNO) directed the start of exploration of a New Attack Submarine Class.

The need for the New Attack Submarine was established in the Mission Need Statement (MNS) dated 10 October 1991. The Mission Needs Statement was validated by the Joint Requirements Oversight Council (JROC) on 23 October 1991.

The New Attack Submarine is designed to be an affordable yet capable platform taking advantage of technological advancements. The New Attack Submarine will, as a minimum, maintain SEAWOLF radiated noise, target strength and non-acoustic stealth characteristics. The New Attack Submarine will be required to maintain covert presence and to be sustained 24 hours per day, with an emphasis on joint forces multi-mission capability. The New Attack Submarine mission areas include: Covert Strike Warfare (Strike), Anti-Submarine Warfare (ASW), Covert Intelligence Collection/Surveillance, Covert Indication and Warning (I&W)/Electronic Warfare (EW), Anti-Surface Ship Warfare (ASUW), Covert Mine Warfare (MW), Special Warfare (SW), and Battle Group (BG) Support. (PEO SUB-X, 1993)

The Defense Acquisition Board (DAB) met in August 1992 and recommended approval of Milestone 0 (Approval to Conduct Concept Studies). The Under Secretary of Defense (SECDEF) approved Milestone 0 via the New Attack Submarine Acquisition Decision Memorandum on 28 August 1992. Milestone I (Approval to Begin a New Acquisition Program) was subsequently approved in August 1994. Milestone II (Approval to Enter Engineering & Manufacturing Development) was approved in June 1995. Low rate initial production (LRIP) is expected to begin in FY-98. Lead ship delivery is expected in April 2004. Initial Operational Capability (IOC) is expected in FY-

06. Milestone III (Approval for Full Rate Production (FRP)) is expected in FY-08. (PEO SUB-X, 1993)

Electric Boat, the design contractor for the New Attack Submarine, chose IBM/Dassault's computer-aided three-dimensional interactive (CATIA) digital design system and CATIA data manager (CDM) for the base set of computer-aided design, engineering, and manufacturing application programs in the design and production of the New Attack Submarine (Kowenhaven and Harris, 1997). CATIA and CDM allow the design data to be available on a digital network. This allows production to proceed without manual or graphical hardcopy transfer of the data. The same design data can drive numerically controlled manufacturing processes using the design database rather than physical drawings. (Kowenhaven and Harris, 1997) CATIA is a leading computer-aided design/computer-aided manufacturing (CAD/CAM) application. CATIA was developed by Dassault Systemes and is distributed, marketed and supported worldwide by IBM. CATIA is used in the aerospace, appliance, architecture, automotive, construction, consumer goods, electronics, furniture, machinery, medical, mold and die, and shipbuilding industries. CATIA provides for a STEP interface to exchange data. The CATIA/CDM System has the capability to generate design data in the internationally recognized STEP format. (IBM/Dassault, 1997)

2. The Rapid Acquisition of Manufactured Parts (RAMP) Program

Concept development of the Rapid Acquisition of Manufactured Parts (RAMP) Program was begun in 1982 by the Naval Supply Systems Command (NAVSUP). The

purpose of the program was to fill a need in the Navy's supply system to obtain hard-to-procure, out-of-production spare parts for older weapon systems. These parts were becoming increasingly more expensive to procure in the limited quantities needed due to nonavailability of data packages for the weapon systems and the diminishing domestic manufacturing sources for production of these parts. The RAMP program was designed to use intelligent digital data in a computer integrated manufacturing (CIM)/flexible manufacturing environment to produce these parts quickly and at a lower unit cost. (Peterson, 1993)

Intertwined with the problem of finding contractors, procurement lead time was becoming excessive. The late 1980's average lead time for no-longer-available parts was approximately 300 days (Peterson. 1993). A goal of the RAMP Program is to reduce that lead time to less than 30 days.

Technology in manufacturing, although at the core of the RAMP Program, is not the only technological advancement involved in the RAMP Program. The RAMP Program calls for the application of technology in the Request For Proposal (RFP), bid preparation, bid submission, bid evaluation, and contract award. These elements can easily make use of Electronic Commerce and Electronic Data Interchange technology.

Physical development of RAMP hardware and software was initiated under an R&D contract with the South Carolina Research Authority (SCRA) in 1987. SCRA is a not-for-profit, state-sponsored organization dedicated to encouraging technological innovation within South Carolina. The contract called for SCRA to exercise overall technological management of the RAMP Program. SCRA employed the resources of a

consortium of four private industry firms to develop the required technological applications in a team effort.

The fundamental RAMP Program objective was "To develop and prototype, for technology transfer to the commercial industrial base, the capability for data-driven, just-in-time, low-volume manufacturing of hard-to-obtain items." (SCRA, 1997) The secondary program objectives were stated as: "Reduction in acquisition lead times, particularly for items of supply with limited sources; Increased competition via technical data packages developed through reverse engineering; Continuous improvements to manufacturing through development and deployment of modern process control and data management capabilities." (SCRA, 1997)

Progress on RAMP was made quickly. The first RAMP "cell" was ready to begin manufacturing parts in late 1990. This cell was located at the Naval Aviation Depot at Cherry Point, North Carolina.

In order to achieve the transfer of the technological use of intelligent digital data to the commercial manufacturing base, a goal was to first demonstrate the capabilities of these processes by calling upon specific areas of manufacturing expertise within the Department of Defense operated manufacturing facilities. RAMP processes have been implemented at 16 sites throughout the U. S. Defense Depot maintenance and defense supplier community including Army and Air Force Sites. The specific processes implemented at these sites are focused on each site's mission and specific manufacturing area of expertise. For example, The Naval Aviation Depot at Cherry Point, North Carolina repairs aircraft. For this purpose it requires both the capability to manufacture

general mechanical parts as well as the more specialized capability to manufacture aircraft engine blades and vanes. (SCRA, 1997)

The RAMP Program's application of intelligent digital data is no longer a Department of Defense "in-house" system. The desired goal of transferring this technology to the commercial industrial base has been achieved. Seven private sector organizations have implemented or will shortly implement intelligent digital data processes in support of the RAMP Program.

Table 2.1 lists the current and projected sites along with their specific RAMP process capabilities. SCRA, the technology developer maintains a complete program capability. Additionally, a site has been established in Leeds, England in an effort to afford the United Kingdom Defense Ministry the same capabilities the RAMP Program provides to the United States Department of Defense.

a. RAMP Process Capabilities.

Because there are varying capabilities within RAMP facilities, the capabilities indicated in Table 2.1 are described below:

- RAMP Product Translation System for Mechanical Parts (RPTS MP). This function allows the conversion of the design data into intelligent digital data and allows for reverse engineering in the event design data are not available.

RAMP FACILITIES									
LOCATION	RPTS MP	MP	EB/ VF	RAMP LITE	RPTS PWA	PWA	GPPE	QRM	QPM
ANNISTON ARMY DEPOT		X					X		X
BABCOCK & WILCOX		X					X		X
ASO/ICP PHILADELPHIA								X	
NADEP CHERRY POINT		X	X						
NAWCADI INDIANAPOLIS					X	X			
NSWC CRANE					X				
NSWC LOUISVILLE	X								
ROCK ISLAND ARSENAL	X								
SCRA, CHARLESTON	X	X	X	X	X	X	X	X	X
SMALC SACRAMENTO						X			
SPCC/ICP								X	
TEXAS INSTRUMENTS							X		X
TOBYHANNA ARMY DEPOT						X			
TRF KINGS BAY				X					
USS EMORY S. LAND				X					
CNC INDUSTRIES									X
YOKOSUKA SRF				X					
WARNER-ROBINS ALC									X
CAMPBELL ENGINEERING									X
DYNETICS INCORPORATED									X
UNITED DEFENSE									X
FOCUS: HOPE							X		X
LEEDS, UK	X								X
DSCR RICHMOND								X	

Table 2.1. Current RAMP Facilities and Capabilities (RAMP, 1997).

- **Mechanical Parts (MP)**. This function allows for the manufacture of mechanical parts from intelligent digital data.

- **Engine Blade and Vane Fabrication (EB/VF)**. This function allows for the manufacture of aircraft engine blades and vanes.

- **RAMP Lite**. This function was designed to assist Navy Intermediate Maintenance Activities (IMAs) to lower costs and improve efficiency by providing a system that facilitates the production of a wide variety of mechanical parts. This system can be located shipboard to provide a deployable RAMP facility. A RAMP Lite capability is installed at the Trident Refit Facility in Kings Bay, Georgia. This facility is the Intermediate Maintenance Facility for the Trident Ballistic Missile Submarines homeported in Kings Bay. Additionally, RAMP Lite has been installed on board the USS Emory S. Land (AS-39), a submarine tender homeported in Norfolk, Virginia, as well as at the Ship Repair Facility (SRF) in Yokosuka, Japan. The Yokosuka SRF is the intermediate maintenance activity for the U. S. Navy ships forward-based in Yokosuka.

- **RAMP Product Translation System Printed Wire Assembly (RPTS PWA).** This function converts design data into intelligent digital data for manufacture of Printed Wire Assemblies (PWA). PWAs are the most common form of printed circuits. They are used in those applications in which the maximum number of interconnections (conductors) in a given area are desired, while minimizing cost. (McGraw-Hill, 1987)

- **Generative Process Planning Environment (GPPE)**. The GPPE is a state-of-the-art process planning system that can accept and process intelligent digital product data to quickly produce the bill of material, the bill of activities (or routing), and time estimates associated with the manufacture of the product described by the intelligent digital data. The Quote Preparation Manager can then use this information to rapidly produce highly accurate job quotes. (SCRA, 1997)

- **Quote Request Manager (QRM)**. This capability allows Navy procuring activities to prepare electronic RFPs and facilitates receipt and evaluation of electronic proposals. The activities which have QRM capability include the Ship's Parts Control Center (SPCC) and Inventory Control Point (ICP) in Mechanicsburg, Pennsylvania, the Aviation Supply Office (ASO) and Inventory Control Point (ICP) in Philadelphia, Pennsylvania, and Defense Supply Center Richmond, Virginia. These activities are the item inventory managers for the parts in the Navy and Defense Logistics Agency (DLA) supply systems and are therefore the activities responsible for obtaining a part when needed. These are the activities that request quotes from contractors to manufacture parts.

- **Quote Preparation Manager (QPM)**. This capability allows a RAMP facility to prepare quotes for items requested for bid. The goal of the RAMP Program is to "enroll" as many manufacturers as possible and provide them with, as a minimum, QPM capability.

3. RAMP Program Results

The Naval Air Warfare Center, Indianapolis installed a printed wire assembly cell with both RPTS PWA as well as PWA functions. Their 1996 production showed a 24 percent cost savings from traditional manufacturing, a 27 percent reduction in total cycle time, a 83 percent reduction in rework, and a 74 percent reduction in the cost of repeat orders. The Naval Engine Airfoil Center at Cherry Point, North Carolina is demonstrating cost savings in excess of $20 Million annually. (SCRA, 1997)

The RAMP facility at the Anniston Army Depot produced over 50,000 parts in its first year. As of March 1997, Anniston had filled over 1700 orders, providing 136,036 parts primarily to support Army combat vehicles. According to Anniston, if the material is on hand, customers can expect a one-hour turnaround on repeat orders (Interview-Z, 1997).

RAMP has proven very valuable in the support of the AVENGER Class Mine Countermeasures and OSPREY Class Coastal Minehunter ships. Both classes have low magnetic signature, Italian-made Isotta-Fraschini Diesel Engines installed. These diesel engines were experiencing a mean time between failure (MTBF) of less than 250 hours and a supply material availability (SMA) of less than 50 percent. Procurement lead times for certain parts had reached 480 days. After RAMP involvement in the program, supply material availability (SMA) was increased to greater than 90 percent and the 480-day lead time had been reduced to 10 days. (Interview-Z, 1997)

III. IMPLICATIONS FOR NAVY SUPPLY SUPPORT

> Nevertheless, the world remains a dangerous and highly uncertain place, and the United States likely will face a number of significant challenges to its security between now and 2015...To sustain this position of leadership, the United States must maintain ready and versatile forces capable of conducting a wide range of military operations... Absent a marked deterioration in world events, the nation is unlikely to support significantly greater resources dedicated to national defense than it does now.
> (Cohen, 1997)

These excerpts from the *Report of the Quadrennial Defense Review (QDR)* suggest that the United States military will continue to have to do more with less. The issue developed in this chapter is formed from the following statements: (1) The Navy operates a varied arsenal of weapon systems. The commitments for the forces operating these systems and therefore Operating Tempo (OPTEMPO) are not decreasing. (2) The funding to support the Navy's operations is not growing. (3) In order to support these operations the Navy must look for more cost effective ways of conducting its support functions--especially in light of the focus of the QDR on force modernization. (4) The Navy maintains an expensive spare and repair parts inventory. (5) The Navy has developed a technology application (RAMP Program) for the use of digital design data which has proven itself capable of the timely and cost effective manufacturing of no-longer-available parts; and (6) The Navy's newest weapon systems under procurement are using advanced technology in computer-aided design and manufacturing.

This series of statements is explored in this chapter. This exploration leads in subsequent chapters to the answers to the following questions. Can the Navy apply

current advances in digital data technology in the design and manufacture of its weapon systems to reduce the spare and repair parts inventory? And if so, what are the costs involved?

A. DEPARTMENT OF DEFENSE BUDGET

"The greatest challenge we face in this new world order is the constrained budget environment in which we operate" (Perry, 1996). The Department of Defense Budget continues to be at the forefront of the debate over cuts in discretionary spending. The 1998 Federal Budget as submitted by the President totals $1.69 trillion. Of this amount, $260 billion (15 percent) is for defense spending. Domestic spending totals $284 billion (17 percent). The remainder of the budget is earmarked for entitlement spending. Of the funds cited for discretionary spending, defense spending is roughly 47 percent. (OMB, 1997)

There has been no real growth in defense spending since 1985 and, in fact, from 1985 to 1997 there has been a 40 percent decline in real budget authority for the Department of Defense (Perry, 1997). The Quadrennial Defense Review analysis of America's defense needs from 1997 to 2015 projected stable annual defense budgets of roughly $250 Billion in constant FY 1997 dollars (Cohen, 1997). A "flat-line" budget in real terms combined with a relatively constant worldwide military commitment and new weapon systems procurement highlights the funding issue facing the military.

B. DEPARTMENT OF DEFENSE SPARE AND REPAIR PARTS INVENTORY MANAGEMENT

The Department of Defense manages the largest inventory in the world. The value of this inventory at the end of FY-96 was $67 billion (constant FY-95 dollars) (Emahiser, 1997). The Department of Defense inventory is comprised of the inventory managed by each service as well as that managed by the Defense Logistics Agency (DLA). Despite progress in reducing this inventory since 1989, when the value was $107 billion (constant FY-95 dollars), and the Secretary of Defense's forecasted end-of-year value for FY-03 of $48 billion (constant FY-95 dollars), the management of the Department of Defense inventory system has been called into question in numerous General Accounting Office (GAO) reports. (Emahiser, 1997; GAO/NSIAD-96-156, 1996; GAO/NSIAD-95-2, 1994; GAO/NSIAD-95-85,1995)

The GAO has made numerous recommendations to reduce not only the level of inventory but also the costs of maintaining the inventory. In 1995 the Department of Defense spent approximately $24 billion to maintain its inventory (GAO/NSIAD-96-156, 1996). This figure includes the costs of buying, storing, repairing, and issuing the parts. The recommendations to reduce the cost of maintaining the inventory include adoption of best commercial practices, reducing acquisition lead time, and improved analysis for diminishing manufacturing sources and material shortages. (GAO/NSIAD-96-156,1996; GAO/NSIAD-94-235,1994; GAO/NSIAD-95-2, 1994; GAO/NSIAD-95-85,

1995; GAO/NSIAD-95-142, 1995) The constrained budget and recommendations to reduce the inventory costs are key factors in the motivation for this study.

C. NAVY INVENTORY MANAGEMENT

Because the focus of this investigation is on the application of intelligent digital technology to reduce the spare and repair parts inventory for the New Attack Submarine, the structure, pricing, and operation of the Navy's inventory system is discussed next to provide the reader with a context to understand potential applications of intelligent digital data within this system.

1. Structure and Pricing of the Navy Inventory System

Ship and submarine spare and repair part inventories are generally separated into two categories, Coordinated Shipboard Allowance List (COSAL) and the Wholesale Inventory. The COSAL is that portion of the spare and repair parts inventory that is maintained onboard the ship and is sometimes referred to as on board repair parts (OBRP). The wholesale inventory is that which is maintained at DLA Depots. The inventories are structured using several different models. The underlying theme to all the models, however, is that a demand for each part is calculated based on several factors. These factors include the part population in the entire weapon systems inventory (not just on a per platform basis), the predicted or established failure rate of the part, the criticality of the part to the subsystem, and the criticality of the subsystem to the weapon system mission.

An example of a COSAL model is the "0.5 FLSIP Plus" model used for the non-steam and electric, hull, mechanical and electrical parts (i.e., non-propulsion plant related parts which are hull, mechanical or electrical in nature) for the SEAWOLF Class . The acronym FLSIP stands for Fleet Logistics Support Improvement Program. In this model a part qualifying as a demand-based allowance item (item depth to satisfy 90 percent of demand over a 90-day period) must have an expected usage greater than once per quarter. Items with less than this expected usage but greater than once every two years qualify as insurance items for mission vital systems/parts and are stocked at a depth of one replacement unit. The "plus" term refers to additional parts that are added based on CASREP or 3M usage data or technical overrides[2]. (NAVSUP 553, 1991)

The general philosophy of the wholesale model starts with demand being calculated from the failure rate (predicted or demonstrated) multiplied times the total population (population of the part in the entire defense arsenal). Using this predicted demand value, a cost difference analysis (COSDIF) is performed to determine whether it is more costly to stock the part or not stock the part. The COSDIF is an expected value analysis that compares the first two years' total expected costs of stocking an item to the expected cost of not stocking the item and subsequently needing it over the same time period. In performing the COSDIF analysis, consideration is given to the costs of

[2] The Navy's Equipment Casualty Reporting System (CASREP) is used to document degradation to weapon system capability due to material failure. The system serves as both a combat capabilities status reporting system for operational commanders as well as a logistics support requirements identification and feedback system. The Navy's Maintenance and Material Management (3M) System is the guidance and reporting system for preventive and corrective equipment maintenance aboard all ships and applicable shore stations.

procurement, cost of issuing, holding cost, premium paid when buying on demand, shortage cost, frequency of demand, frequency of procurement, demand, unit price, and production lead time. If the COSDIF analysis shows it is cheaper to stock than not stock the item, then the item is stocked as a demand-based item with an initial depth of expected demand during a procurement lead time plus one quarter, plus safety stock.

In addition to "demand-based" items, items are also identified to be stocked as "non-demand based" items. Non-demand based items can be separated into several categories. The two main categories of non-demand based items are insurance items and Numeric Stockage Objective (NSO) items. An insurance item is an essential item for which no failure is predicted through normal usage, but, if failure is experienced or loss occurs through accident, abnormal equipment/system failure or other unexpected occurrences, lack of an immediately available replacement would seriously hamper the operational capability of the weapon system (NAVSUP 553, 1991). An NSO item is an essential item for which the probability of demand is so low that it does not meet the demand-based stockage criteria. If the lack of a replacement item would seriously hamper the operational capability of a weapon system the item is stocked as non-demand-based at a depth of one or two units (NAVSUP 553, 1991). Other categories include items needed on a non-recurring or sporadic basis, items procured on a life-of-type buy, and items not fully consumed during a one-time or non-repetitive program but which should be retained for possible future use.

Customers of the Navy/DLA supply system make purchases from the DLA Depots. These purchases are made through the Military Standard Requisition and Issue

Process (MILSTRIP). Each customer requisition serves as both a communication of a customer requirement to the cognizant ICP or Defense Supply Center (DSC) as well as a funded customer order.

Inventory items purchased by the supply system are held at DLA Depots until they are requisitioned by a customer. The amount reimbursed by customers to the depot for the part is the sum of the procurement cost of the part plus a surcharge or cost recovery factor. This cost recovery factor is comprised of all of the depot's costs of doing business including the cost of supply operations, transportation, inventory losses, obsolescence, price stabilization/inflation, and inventory maintenance, as well as a portion of the DLA Headquarters operating costs. (Naval Postgraduate School, 1996; Ahern, 1991)

The cost recovery factors vary from fiscal year to fiscal year. The variations are due to the requirement for the working capital funds in which the supply management business areas operate, to attempt to break even. The cost recovery factor must be adjusted on an annual basis to target a break-even point with the forecast business volume. The variation in cost recovery factors is shown in Table 3.1. This table displays the cost recovery factors for NAVICP since FY-91. Fiscal Year 1991 was chosen as the lower bound on the historical values because it was it was in FY-91 that Defense Management Review Decision (DMRD) 901 took effect. DMRD 901 mandated that all the costs of doing business in the supply management business area now be recouped using the surcharge. The DLA cost recovery factors for this period were not available (see Appendix B). The factors are shown graphically in Figure 3.1.

History of Cost Recovery Factors for NAVICP									
	1990	1991	1992	1993	1994	1995	1996	1997	1998
NAVICP Consummable	17.1	30.9	27.0	34.6	51.8	58.1	13.5	20.0	52.7
NAVICP DLR (Standard)	10.7	23.3	23.8	33.4	56.1	62.7	17.8	34.2	68.3
NAVICP DLR (Net)	18.0	26.5	21.9	30.0	51.0	48.3	3.4	17.2	47.5

Table 3.1. History of NAVICP Cost Recovery Factors

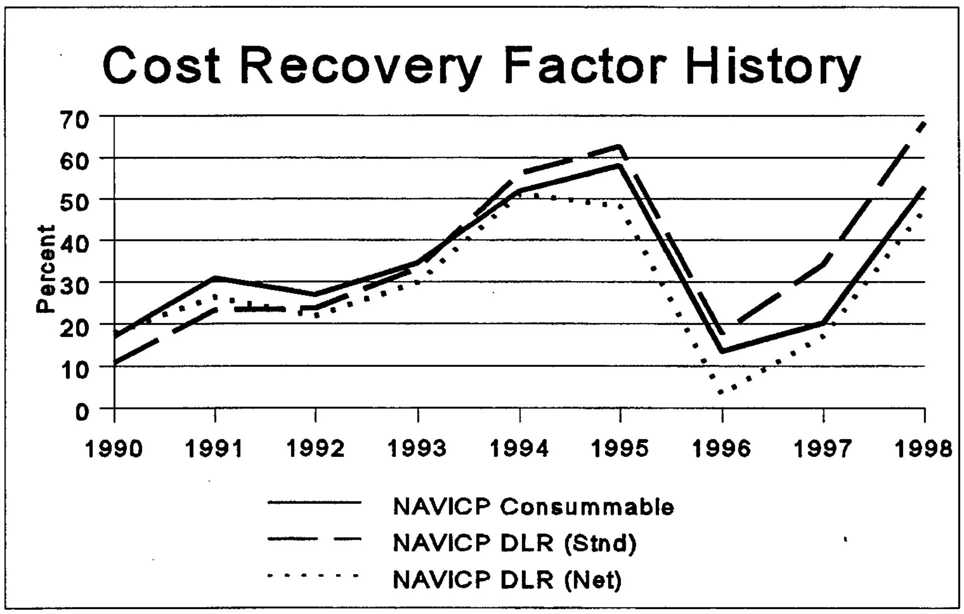

Figure 3.1. History of NAVICP Cost Recovery Factors

The customer funding for spare and repair parts is allocated from the Operations and Maintenance Navy appropriation category. These funds are appropriated on an

annual basis. The Navy/DLA supply systems operate in the Supply Management Business Area of the Navy Working Capital Fund or Defense Working Capital Fund. These Working Capital Funds operate as revolving funds in that the reimbursements from customers are used for restocking the parts inventory with a break-even objective. However, the Working Capital Funds do receive funds from procurement accounts to support outfitting weapon systems entering service. Currently, the Navy Inventory Control Points manage only about five percent of the inventory that supports its weapons systems. This five percent is predominantly depot level repairable items (DLRs). The other 95 percent is consummable items which are managed by DLA. (Interview-AC, 1997)

2. Operation of the Navy Inventory System

The Navy inventory system, despite the fact that the RAMP Program began in 1990, continues to operate primarily outside the intelligent digital data environment. An overview of operations both in and out of an intelligent digital data environment is provided.

a. Operations in the Absence of Intelligent Digital Data

When a spare part is needed for a ship or aircraft, a requisition is submitted to the cognizant supply department supporting the activity. If the part is held in stock, it is issued to fill the requisition. If the part is not stocked locally, the requisition is passed to an ICP or DSC, which are connected via computer to all DLA Depots. If the part is

available in the supply system, the DLA Depot nearest the requiring activity ships it. This sequence of events occurs for over 80 percent of the requisitions submitted. In the case where the required part is not available in the supply system, the requirement is passed to the ICP's or DSC's procurement activity. The procurement activity then attempts to purchase the part.

In order to be able to purchase the part, the procurement activity requires the specifications of the part. If the specifications are available, the procuring activity issues a Request for Proposal (RFP). If the specifications are not available, the part has to be reverse engineered to obtain the necessary design specifications in order to issue an RFP. The RFP invites interested contractors to submit a proposal for manufacturing the part. The interested contractors then submit a bid indicating cost and schedule. The procuring activity evaluates the proposals submitted and awards the contract based on "best value" to the government. (Burton, 1990; DOD 5000.2R, 1996)

b. Operations in the Intelligent Digital Data Environment

Intelligent digital data may be able to provide supply support when it is determined that the part is not available within the Navy's/DLA's supply system. The process to use the intelligent digital data is multi-step. The part is first analyzed for the potential for CIM/RAMP manufacturing. This can easily be done if the design data are available in digital format. It could also be done by examining hard copy design data. If the part appears to be within the capabilities of CIM/RAMP, then the procuring activity would transmit an RFP over an electronic network with the specifications for the

necessary part in digital format[3]. The activities in the intelligent digital data/RAMP network would receive the RFP via computer. A CIM/RAMP cell receiving the RFP would evaluate both the cell's capability and capacity to produce the part. If capability and capacity exist within the cell, then the cell produces and transmits an electronic bid or quote. The bidder who provides best value to the government is then awarded the contract electronically. (Burton, 1990; DOD 5000.2R, 1996)

Intelligent digital data do not provide all of the answers to the spare parts acquisition problems. The supply system operations with intelligent digital data are still hampered by the non-availability of design data. If the design data are available, but not already in digital format, the data must be converted to digital format. This conversion comes at a cost which is discussed in Chapter V. If the design data are not available, then the part is reverse engineered and the resulting design data are generated in digital format. In order to reverse engineer a part, the reverse engineering facility must have the part. Retrieving the part adds additional time to the replacement process.

D. POTENTIAL FOR SAVINGS

The supply component of the Navy's mission consumes 50 to 65 percent of the Navy budget (NAVSUP 553, 1991). In 1996 the Navy inventory was valued at $33.7 billion (GAO/NSIAD-97-47, 1997). These two statements, in company with the budget

[3] The use of electronic commerce is the preferred method. The RAMP system as described in Chapter II is still in its relative infancy with respect to creation of the "RAMP network" of manufacturers. In reality the RFP and bids may not be transmitted between QPM and QPR capable organizations.

figures and trends discussed above, suggest the potential for savings with the application of intelligent digital data to the spare and repair parts inventory exists. Even a small percentage savings becomes a worthwhile objective.

Under the current system, the wholesale inventory for the submarine force can be expected to increase. The decrease in the total number of submarines in the force will decrease both the range (number of different parts) and depth (quantities of each part) of the wholesale inventory required to support the submarine force. The addition of a new class of submarine will increase the range and depth requirements of the wholesale inventory. The mandate to prototype the first four hulls of the New Attack Submarine will further increase the range of the wholesale inventory. Traditionally, force modernization has resulted in significant inventory growth as parts were purchased to support new weapon systems (Emahiser, 1997). Simply, the more diverse the submarine force makeup, the more diverse the inventory requirements, the larger the wholesale inventory, and the more costly the inventory support for the submarine force.

The Navy supply system, despite its significant experience from years of buying, holding and providing parts when needed and its complex computer models and highly capable computer systems, must still make tradeoffs between affordability and responsiveness in sustaining the complex and constantly changing arsenal of weapon systems. These tradeoffs can benefit from the application of intelligent digital data technology.

IV. METHODOLOGY

Performing opinion, archival, and empirical research enables a systematic interpretation of the costs of applying significant advances in the use of digital data in the production and manufacturing environment to the Navy's inventory system. The inherent weaknesses of the research techniques and biases of the researcher were hopefully minimized through the use of these multiple research methods and through a conscious awareness of the deficiencies and their impact upon data gathering and analysis.

The methodology required for this research was divided into the following phases: (1) review of pertinent literature, (2) interviews with individuals at associated agencies, (3) collection of program data, (4) reduction of data, (5) analysis of data, and (6) conclusions and recommendations. This research identified specific costs of the use of intelligent digital data within the Navy supply system. The combination of opinion, archival, and empirical research in the literature review, interviews, and data collection provided a balance of qualitative and quantitative data. This approach increased the probability of achieving success in examining the potential application of intelligent digital data to the Navy supply system.

A. REVIEW OF PERTINENT LITERATURE

A review of the pertinent literature on the New Attack Submarine Program, the SEAWOLF Submarine Program, the RAMP Program, the Navy and other Department of Defense (DOD) Inventory Systems, Flexible Manufacturing Technology/Computer-

Integrated Manufacturing, and Federal Acquisition Regulations was conducted. This literature was specifically examined to identify the difficulties in applying CIM/RAMP to the New Attack Submarine. Primary information was collected from instructions, directives, reports, and contracts supporting the New Attack Submarine, SEAWOLF, and RAMP Programs and the DOD supply system. Secondary information was collected from periodical and journal articles as well as related theses and General Accounting Office reports. This archival research provided a basis for formulating the subject matter of the opinion research. It also provided a comparative framework when evaluating the results of opinion research.

B. INTERVIEWS

Interviews were conducted over a period of eleven months. Interviews were conducted with 36 individuals from seven different organizations. Interviews were conducted with representatives of the following commands and agencies: Naval Supply Systems Command (i.e., RAMP Program Office, Inventory Control Points, and Fleet Material Support Office (FMSO)), Naval Sea Systems Command (i.e., New Attack Submarine and SEAWOLF Submarine Programs), Defense Logistics Agency and the South Carolina Research Authority (SCRA) RAMP Program Office. The purpose of the interviews was to gain insight and perspective into the programs beyond that which is available in the literature, as well as obtain data not available elsewhere.

Individual viewpoints, group norms, and the culture of the organizations were considered in evaluating the data collected during the interview process. Opinion research

helps reveal the attitudes, beliefs, and understandings of key individuals. However, the researcher's design of questions, selection of interview candidates, and the method of the interview are inherent biases introduced into the research.

The majority of the interviews were conducted by telephone and electronic mail. Individuals typically responded differently to the researcher on the telephone and through electronic mail then in a face-to-face interview. The interview medium could influence the interviewees' descriptions and opinions of why contracts were structured as they were, why certain data were procured and the associated costs. This is one of the inherent drawbacks to conducting research on organizations which are geographically located thousands of miles and several time zones from the researcher.

C. COLLECTION OF PROGRAM DATA

Data were collected from submarine program offices as well as from the Naval Supply Systems Command to attempt to quantifiably define two aspects of the research:

(1) What percentage of parts from the New Attack Submarine could be manufactured in an intelligent digital data environment?

(2) What is the cost of obtaining the design data to be able to manufacture the parts in an intelligent digital data environment?

The goal of this part of the data collection was to identify a set of parts from the New Attack Submarine that would be likely candidates for manufacture in a CIM/RAMP facility. The analysis was conducted on a single subsystem of the New Attack Submarine.

Criteria were established for selecting the subsystem These criteria are discussed in Chapter V. An example of the criteria used is that candidate choices were limited to those systems that did not have security classification restrictions. This selection criterion was intended to avoid limitations on the handling and distribution of the thesis. Alternate candidate subsystems were also identified in the event that data were not available for the primary system selected. The Reelable Towed Array Handling System was chosen because it satisfied the established criteria. This is the system that allows the submarine to stream and retrieve the towed sonar array. The towed sonar array is part of the acoustic sensor suite on board the submarine. The handling system has a cross-section of types of components. They include hydraulics, seawater systems, mechanical cable handling systems as well as control and indicator circuitry and all associated connectors. The intention was to evaluate a system on the New Attack Submarine to identify candidate parts for potential CIM/RAMP manufacture. However, the system drawings for the New Attack Submarine were not fully approved and available for review. The alternative system selected was the similar system on the SEAWOLF submarine. During the course of data collection on the SEAWOLF RTAHS, it was determined that the appropriate documentation and drawings were not available to the researcher. This caused data collection to proceed to the second alternate research path, the Reelable Towed Array Handling System (RTAHS) on the LOS ANGELES (688) Class submarine. A review of available drawings and technical manuals and discussions with program personnel confirmed that the system designs were very similar. A complete parts lists was obtained for the LOS ANGELES Class RTAHS.

The parts analysis was conducted to identify parts that were potential candidates for RAMP manufacturing based on their design characteristics.

Determination of the cost of the design data was also attempted. However, due to the lack of documented data on even current shipbuilding contracts in the Naval Sea Systems Command program offices, this effort proved impossible. The contracts and records lacked the metrics to track and report the costs of the data.

D. VALIDATION OF DATA

The data collected were first reviewed to ensure that no gaps or contradictions existed. The data were then reduced to a manageable format by separating them into categories for further analysis. Five categories were established to describe the type of part and whether this part was CIM/RAMP manufacturable. Cross-referencing checks were conducted between the part nomenclature and the system drawings to ascertain the proper category of part.

Much of the data used in the analysis were from the interviews. In many cases actual numbers were unavailable from archival data sources to validate or clarify the interview data. The lack of documented data resulted primarily from the fact that cost figures and acquisition decisions discussed in the interviews were often from preliminary negotiations which were never included in the final contract.

In order to minimize researcher bias, the researcher listened to question responses, observed individual behavior and analyzed the data before conclusions were drawn. The researcher attempted to minimize the expression of his own emotions, beliefs, or opinions

about the subject of the interview or in response to the interviewee's responses during the research.

E. ANALYSIS OF DATA

The data collected was used to construct a net present value estimation model. The model was used to estimate the maximum price the Navy should pay to obtain intelligent digital data for parts over a variety of combinations of part-specific characteristics. Finally, both the CIM/RAMP manufacturable part analysis and the net present value estimation model were used to obtain an estimated range for the potential for cost savings with the application of intelligent digital data.

V. DATA PRESENTATION AND ANALYSIS

This chapter discusses the data collected to conduct an analysis of the costs of using intelligent digital data to reduce the spare and repair parts inventory for the New Attack Submarine. The discussion includes information concerning the technical feasibility of such an application, the need or market for such an application, a measure of the Navy's interest in such an application, and the process and costs associated with acquisition of the design data.

A. TECHNICAL FEASIBILITY OF INTELLIGENT DIGITAL DATA APPLICATION

The question of technical feasibility of the application of intelligent digital data to reduce the spare and repair parts inventory of the New Attack Submarine depends both on the availability of the design data in intelligent digital format as well as the technology to employ that data in parts production. Recall from the discussion in Chapter II that the manufacturing technology has been developed through the RAMP Program. Thus, the remaining question is whether the design data are available in an appropriate intelligent digital format which can be used by this technology.

Design data acquisition has been an "on again, off again" experience during recent Department of Defense shipbuilding programs. In order to answer the question of whether the design data are available in intelligent digital format, the question must first be answered as to whether it is available in any format. Design data, when provided, have

historically been in hardcopy format as well as microform/microfiche. Because the decisions made for current programs were in part based on the data acquisition experience of previous programs, decisions for previous programs were also analyzed to gain insight into the design data acquisition process for the New Attack Submarine.

1. Historical Perspective on Design Data Acquisition

Examining the acquisition strategies from a recent submarine program was helpful in establishing what design data were obtained, why they were obtained and at what cost. The SEAWOLF Program strategy is examined. Additionally, the acquisition strategy for a specific equipment that was intended to be installed on a number of classes of submarines is also examined. This equipment acquisition strategy is examined both from the perspective of strategy for design data acquisition as well as the problems associated with design data acquisition.

a. The SEAWOLF Program

The SEAWOLF Program acquisition strategy initially included the procurement of a complete set of design data. The purpose for obtaining all of the design data was to maximize competition. "With 29 hulls to build, this translates into a lot of pumps and valves" (Interview-A, 1997). If the government owned the data, then it could be made available to contractors other than the developer to obtain the lowest price, using competitive bids. New contractors wouldn't have to recoup the up-front design costs because they would be building to an existing print (Interview-A, 1997). The only design

data that would not be acquired are that which contractors were not willing to provide. When the Level III design data requirement was included in the original contract, no systems, equipment, or components were excluded or stated as not available by the prime contractor/design yard (Interview-A, 1997).

However, there are at least two reasons for contractors being unwilling to supply the design data. The first is the proprietary nature of the data. (Interview-B, 1997; Interview-G, 1997; Interview-O, 1997) Some contractors considered the design data proprietary, how the contractors manufactured the part was what provided them with a competitive edge in the industry. For others the proprietary concern was the "guaranteed" future income stream from being the sole contractor of the part(s).

One interviewee offered his opinion on the unwillingness of industry to forfeit design data without "appropriate" compensation. A likely reason for the often cost prohibitive nature of the data is as a hedge against the recent volatility in major weapon system acquisition contracts (e.g., SEAWOLF). Contractors have been "burned" by the political volatility surrounding major defense weapons acquisition programs. Programs that have been drastically cut back or canceled in total have made contractors very wary of investment in new programs. Proposals were submitted and contracts signed with prices that did not necessarily cover contractor costs, much less provide profit in the short term, but were expected to recoup costs and provide profit in the long term. When the program was subsequently canceled or drastically cut back, the contractor was left "holding the bag" for the startup and initial tooling costs, with little hope of accruing future profits. It is this type of experience that causes the price quotes for design data in new programs to

be "marked up" as a hedge against program cancellation and to assure a future income stream. (Interview-B, 1997)

Some contractors were unable to provide the design data in intelligent digital format. In some instances, despite the fact that design data for the part could be made available, the manufacturing process for that part could not be captured in digital form. Portions of such processes are performed by master craftsmen whose actions and intuitive feel for their craft preclude their duplication by numerically controlled machines. This was definitely the case for certain components which have sound-quieting tolerances associated with their operation. (Interview-F, 1996)

The SEAWOLF Program budget included approximately $3.0 million for acquisition of design data for the class in the lead ship contract (SSN21). The program was budgeted to spend another $1.5 million for design data for the class in the contract for the second hull (SSN22). The plan for the remainder of the class was to budget approximately $1.0 million per submarine thereafter to obtain design data for the class. (Interview-A, 1997; Interview-P, 1997) For this 29-ship class, the total amount to be spent on design data for the class would have totaled over $30.0 million. By the time the $30.0 million would be spent there would be a sizeable collection of design data. Originally, there was no prioritization of what design data were the most important to obtain first. The result was that whatever design data became available first was what would be purchased first. Eventually, the necessary data would be acquired; so which came first wasn't of great concern. (Interview-A, 1997; Interview-S, 1997)

However, the number of ships to be funded in this class was drastically cut from 29 to 12 and then down to two. Eventually, a third ship was added to the class. The resultant reduction in class size drastically changed the acquisition strategy for obtaining design data. It was determined that there would be limited utility in obtaining the small amount of design data that could be purchased with the $1.0 million programmed for SSN23. It was determined that the $1.0 million could be better spent elsewhere in the program. Now, with only $4.5 million (from SSN21 and SSN22 contracts) to spend on design data, the program office's revised approach to acquiring design data became "don't just buy one drawing with the $4.5 million." (Interview-A, 1997; Interview-O, 1997)

As of 14 July 1997, the design yard for the SEAWOLF Class, Newport News Shipbuilding (NNS), had 8,131 Level III drawings on file for the SEAWOLF Class (Interview-A, 1997). It is unclear how many or what percentage of the systems and parts are covered by these drawings. The request for this information was made to the program office, however no response was received. A simple average cost per drawing is a relatively meaningless number. Without knowing what systems, equipment, or components are described by these drawings and how many drawings it takes to describe a component, there is no apparent way of calculating the cost of the design data for a particular component. (Interview-A, 1997)

As part of the design contract for the SEAWOLF submarine, the design yard (i.e., NNS) is responsible for technical review of contractor drawings, forwarding of the drawings to NAVSEA for review and approval, and disposition and resolution of NAVSEA comments on the contractor drawings obtained by the design yard as the

procurement activity. The responsibilities also include entering of the drawings into the Master Drawing Schedule (MDS) and scanning the hard copy drawings into the Advanced Technical Information System (ATIS). MDS is the master drawing database for the ship class. ATIS is a digitized index of *Index of Technical Publications (ITP)* and *Ship's Drawing Index (SDI)* products with viewing capabilities. A person can search for an item, call it up, and view it on computer either onboard ship or ashore at support related organizations. (Interview-A, 1997; Interview-B, 1997)

The design yard estimates that the average cost to process a drawing is about $5,000. This figure includes the processing of the drawing as described above. The data on how much the design yard paid to obtain the contractor drawings was not considered an important metric at the time of the acquisition and therefore wasn't obtained and could not be recreated by the program office. (Interview-A, 1997)

2. Current Perspective on Design Data Acquisition - The New Attack Submarine

The technical capability exists within the design yard to produce intelligent digital data in support of the New Attack Submarine. However, the Navy has not contracted to procure intelligent digital data for any part of the New Attack Submarine.

The New Attack Submarine Program, faced with the task of producing "an affordable yet capable platform" (PEO Sub-X, 1993), did not include the requirement to procure any Level III design data (Interview-B, 1997). The design data acquisition experience of the SEAWOLF Program was analyzed and the determination was made that

for the New Attack Submarine, "the benefit was not worth the cost" (Interview-B, 1997). Section 85 of the New Attack Submarine design contract calls for Electric Boat to provide only Level II design data. With respect to Level III data, the contract states, "The contractor shall recommend for approval by NAVSEA the level of drawing detail needed to support life cycle requirements." (PEO Sub-X, 1997) As of 15 July 1997, no recommendations for Level III drawings have been submitted by the contractor, Electric Boat, to NAVSEA (Interview-B, 1997). Since no recommendations for Level III data have been submitted, no Level III data have been purchased and no cost data are therefore available for Level III data for the New Attack Submarine.

There are several issues regarding technical feasibility that require further discussion and clarification. The statement that "the New Attack Submarine is the first weapon system designed solely on computer" (DOD Acquisition Reform Office, 1996), does not mean that the design data for every component are entered in the design database and therefore are available in intelligent digital format. The issues of proprietary data and design data rights of the subcontractors, as well as the efficient employment of the CAD/CAM and supporting database systems, limit the data that are entered (Interview-F, 1997; Interview-B, 1997).

Electric Boat has subcontracts with approximately 10,000 contractors. Approximately 200 of these contractors account for 90 percent of the dollar value of the subcontracts. Electric Boat "does not own the data rights to many of the components" within the New Attack Submarine (Interview-B, 1997). Consequently, Electric Boat does

not have the design data for those components, and therefore cannot enter the design data into the CATIA database. (Interview-B, 1997)

Additionally, it is not clear how many of the contractors have CATIA capability. Generally, CATIA is used by only the large contractors who have to perform systems integration in design of the final product. For those contractors without CATIA, data transfer would have to be conducted from the contractors' CAD/CAM applications to CATIA. This data entry can be performed manually or electronically. But it is likely that additional man-hours would have to be dedicated to a review of the data to ensure completeness, a cost the program managers do not appear willing to bear. (Interview-B, 1997)

An additional problem with providing intelligent digital data is the way in which CATIA is being employed by Electric Boat. The design yard is responsible for the design of the submarine as a functioning weapon system. Functional interrelationships of subsystems and system layout are part of that responsibility. To design the functioning weapon system only requires the characteristics of the components relevant to the overall design of the submarine (i.e., weight, material composition, external dimensions). To enter more data than are absolutely necessary would increase the cost of the design process. (Interview-B, 1997; Kowenhaven and Harris, 1997)

3. Problems Associated with Obtaining Design Data

The analysis thus far has focused on the historical design data acquisition of submarine programs. Several problems with obtaining design data have already been

identified. Further data concerning the cost prohibitive nature of obtaining design data as well as the problem of data accuracy are provided next.

a. Cost Prohibitive Nature

As stated above, design data may be considered proprietary by contractors. Contractors consider both long-run income from producing repair parts as well as whether the data are proprietary and would effectively enable their competition to learn their established trade "secrets". In at least one case involving the SEAWOLF Program, a contractor (This contractor will be referred to by a fictitious name, Contractor V.) was asked to submit a price quote for the procurement of the design data for a series of valves that the contractor was producing to install on the SEAWOLF. Contractor V submitted a price quote of $70 million for the design data for the valves. When asked "why such a high price?" Contractor V replied that to sell the design data would effectively be selling proprietary trade secrets, so that Contractor V would effectively be selling his business. Contractor V estimated the current market value of his business as $70 million. (Interview-B, 1997)

b. Data Accuracy

Some of the difficulties of obtaining the design data go beyond the contractor's subjective valuation of that data. There is another aspect of procuring design data which has a direct impact on cost. The lack of completeness and accuracy of the data would require additional funding to correct or complete and might result in schedule

delays in the delivery of the product. Historically, unless the data provided by the contractor when the weapon system was produced had been proven to be complete and correct, then chances of it being so were slim (Interview-C, 1997). A 1991 estimate by the NAVSUP of the parts that were not stocked and had to be procured by the Navy supply system suggested that 65 percent of the parts being procured lacked complete technical data. (Peterson, 1993)

Currently, numerous reviews are being conducted of component and equipment drawings in the design and approval process for submarine shipbuilding programs. As described earlier, normally the design yard will obtain the drawings from the contractor, review the drawings and forward them to the appropriate program office at NAVSEA for review. Typically, the design yard then receives NAVSEA's comments, resolves any issues with the contractor and resubmits the drawings for final approval. (Interview-A, 1997; Interview-B, 1997) The review process for intelligent digital data would require an additional step of proving the data can be understood by a computer-integrated manufacturing facility. This additional step can be accomplished by running the data through a computer model that simulates the CIM/RAMP facility or actually manufacturing a part in a CIM/RAMP facility. (Interview-N, 1997; Interview-T, 1997) This process of validating the design data is called "data prove out." Data prove out is one means of assuring that the intelligent digital data received are suitable for future use. The following case is a good illustration of the problems associated with design data accuracy.

c. *Case: Atmosphere Control Equipment for the SEAWOLF*

The information for this case was compiled from a series of three interviews conducted at the Naval Sea Systems Command (Interview-C, 1997; Interview-D, 1997; Interview-V, 1997). The individuals interviewed were from the ship design, equipment design, and contracting areas. Citations have been omitted in the case. Contractor names are fictitious.

One example of the various problems that can be encountered in obtaining design data can be found in the acquisition of a specific piece of atmosphere control equipment for the SEAWOLF Submarine. This type of equipment has been on submarines since the STURGEON (637) and BENJAMIN FRANKLIN Class Submarines, built between 1963 and 1975 (Moore, 1983). This equipment helps control the submarine internal atmosphere within healthy limits. The existing equipment had been produced by only one manufacturer (Contractor T) with only slightly updated versions since this equipment was first designed and installed on submarines. The development of a more advanced version of this equipment was begun in 1976 as a spinoff of the Fuel Cell used in the Gemini spacecraft.

The initial contract that NAVSEA signed for this development effort was with Contractor G, a large commercial contractor with significant defense related contracts. The contract called for design development and prototype production of the equipment. Design development continued through the mid 1980's. NAVSEA was not satisfied with Contractor G's initial design. NAVSEA called into question certain aspects of weight and the ability to withstand shock. Separate events resulted in Contractor G

selling the division producing the atmosphere control equipment to Contractor H which was a subsidiary of Contractor U. NAVSEA's dissatisfaction with the original design coupled with the opportunity provided by the conditions of new ownership within Contractor H, caused NAVSEA to initiate a contract modification. The modification involved the addition of new requirements for the equipment that were not in the original contract and modified other requirements in the original contract. The contract would again result in Contractor H providing NAVSEA with both the design and an operational prototype of the equipment. This contract modification cost NAVSEA an additional $15 million.

The resulting set of design (Level III) drawings were known to have significant problems. By all accounts they were "about as bad as anyone had ever seen." The reduction in the number of SEAWOLF units and a realignment of Submarine R&D responsibility within NAVSEA caused the R&D funds for this equipment to run short and severely curtailed any further efforts to bring the drawings up the standard. The drawings were sacrificed in order to produce the hardware, the working prototype. Both fixing the drawings and making the prototype work could not be done with existing funds. Therefore, two contracts were let to Contractor H. The first to refurbish the prototype in order to install it on SEAWOLF (SSN21). The second contract was to bring the design drawings in line with the refurbished prototype. A bid was requested from Contractor H to fix the drawings. Two bids were submitted, one to "fix the drawings right" and the other to "make them better than they were" (an approximate 60 percent fix). Again the lower bid was accepted, and the drawings were somewhat improved. The prevailing

attitude at the time in NAVSEA was that the quality of the drawings wasn't of great concern because everyone expected Contractor H (the developer) to win the competitive bid. Contractor H's past track record on bids for other equipment that it produced for the Navy suggested it would undercut its competition significantly.

The researcher was not able to determine the original cost of the design data for this equipment. The cost data are embedded throughout the R&D contract. The contract to upgrade the drawings was awarded at $1.12 million. This was about 50-70 percent of what it would have taken to produce accurate Level III design data. A worse case estimate is that it would have cost $2.25 million to produced complete Level III design data.

The reason cited for purchasing the design data for the equipment was that it was NAVSEA's intention to compete the production contract because of the number of units to be purchased. NAVSEA planned not only to outfit all 29 SEAWOLF submarines with this equipment, but also to backfit the new equipment on the older classes of submarines that had the old equipment manufactured by Contractor T. Problems with the demand for this equipment began to develop shortly thereafter. The decision was made to not backfit the older classes of submarines with the new equipment. This decision was due in part to the longer-than-anticipated development period as well as the start of the downsizing of the submarine force. Although not specifically part of the SEAWOLF Program, but as equipment that was planned to be installed on SEAWOLF, the demand for the equipment also fell prey to the instability in the SEAWOLF Program.

NAVSEA's initial acquisition strategy for this new atmosphere control equipment was that, after the prototype was built, there would be a production prove out where a sole-source contract would be awarded for a limited number of pieces of equipment to Contractor H in order to verify that the design could be "built to print." After the production prove out, the large buy would be awarded by competitive bid. The turn of events with respect to number of units to be purchased resulted in a drastic change in the procurement strategy. The competitive bid strategy for the large buy was canceled. The new strategy became to contract sole-source for the production prove out to obtain the significantly reduced quantity of units (i.e., three).

One reason it was thought better to go sole-source was that it was believed that the lead-time would be approximately twelve months longer if a contractor other than the designer/prototype builder built the follow-on units. The lead time needed for a new manufacturer was thought to be pushing the deadline for delivery for installation on SEAWOLF. Contractor H had been asked to submit a sole-source price quote for one unit. Contractor H's price quote was $8 million. When asked to reconsider and resubmit, Contractor H again submitted a quote of $8 million. Unfortunately, politics also played a larger role than anticipated in this acquisition process. Contractor T's strong lobbying efforts succeeded in exerting enough pressure that the decision was made to compete the production phase instead of contracting sole-source. Competitive bids were solicited. The contract called for production of two units with an option for a third. Only two contractors submitted bids, Contractor T and Contractor H. The bids were very similar. Contractor H's bid was $5.4 million per unit while Contractor T's bid was approximately

$250,000 less at $5.15 million ($10.3 million for two units with an option for a third). NAVSEA believed the price difference from the sole-source quote and the competitive quote was partially due to competition and partially due to the multiple unit buy. NAVSEA accepted the low bid, Contractor T. The option was eventually exercised for the third unit at a price of $4.9 million.

The partial fix of the known bad design drawings and the subsequent award of the follow-on production contract to the designer's competitor without production prove out has resulted in over 930 Engineering Change Proposals (ECP) being submitted by Contractor T. Over 95 percent of these ECPs have been a result of errors or omissions on the design drawings. This has caused at least 20 contract modifications at a cost to the government of over $3.5 million. Additionally, it caused approximately a two-year delay in delivery of the equipment and a $1.3 million Request for Equitable Adjustment (REA) from Contractor T. The Navy even modified the contract to provide more than $700,000 in Government Furnished Equipment (GFE) to prevent further schedule delays. The unusually high number of changes effectively turned this fixed price contract into a cost reimbursement contract.

One interviewee cited the early initiation of configuration management as a contributing factor in the case. The review and approval process started far too early in the design process, and contributed to the delays experienced by this program.

Cost analysis was not done at the time to determine whether obtaining the design data was cost effective. The prevailing attitude was that sole-source was "bad" and that everything should be competed.

d. *Case Analysis: Atmosphere Control Equipment for the SEAWOLF*

The case presented above provides an opportunity to analyze the factors to consider when procuring design data. The following observations were made from review of the events, intentions, and outcomes of the case.

(1) Attempting to transfer unproven design data from one contractor to another cost NAVSEA an additional $5.9 million and a two-year delay on an original contract for $10.3 million.

(2) No documented attempt to measure the costs of the design data of the equipment could be found.

(3) No documented cost/benefit analysis performed during this contract was identified.

(4) There is a need to prove or test the design data as a product.

(5) The quality of design data can suffer if configuration management is initiated too early in the design process.

(6) World events can change defense policy quickly, requiring dramatic changes in acquisition strategies even after the process has begun.

B. NEED/MARKET ANALYSIS

The answer to the question "Is there a need for the application of this technology to the Navy Inventory System?" must be answered in two parts. The first part answers the question "Is there money to be saved?" while the second part answers the question "Are there parts that can be designated for CIM/RAMP manufacture that could save money?" The Department of Defense Budget and Navy Inventory valuation and maintenance cost figures discussed in Chapter III are summarized below and provided as data to answer the first part of the question.

Summary of Chapter III Data - Potential for Savings	
1998 Federal Budget	$1.69 trillion
1998 Defense Budget	$260 billion
QDR Defense Budget Assumption	$250 billion/yr thru 2015 (1997 dollars)
DOD Inventory value 1996	$67 billion (1995 dollars)
Navy Inventory Value 1996	$33.7 billion (1995 dollars)
DOD Inventory Maintenance Costs 1995	$24 billion (1995 dollars)

Table 5.1. Summary of Chapter III Data - Potential for Savings

An analysis to determine potential CIM/RAMP candidate parts was performed to answer the second part of the question.

1. CIM/RAMP Candidate Part Analysis

In order to establish whether buying design data up front to support CIM/RAMP manufacture of New Attack Submarine parts at a later date is cost effective, there is a need to establish the number of candidate parts that can be CIM/RAMP manufactured. Time, scope, data availability, and security classification constraints limited the analysis to one system or subsystem of the New Attack Submarine. There are approximately 250 such subsystems that comprise the New Attack Submarine (Interview-B, 1997).

In order to properly evaluate a system, criteria were established in order to select a potential system. The first criterion established was that the system had to be unclassified. This would allow the entire thesis to be unclassified and prevent any handling and processing restrictions. The second criterion was that it be a submarine unique system. The purpose of this criterion was to minimize the potential for the system analyzed to have parts/components with a large population in the Navy supply system. The third criterion was that it have a cross-section of parts (e.g., valves, pumps, piping, electrical components, connectors). The purpose of this criterion was to give as representative a sample of types of parts of the entire population of the New Attack Submarine as possible. The last criterion was that similar systems exist on previous classes of submarines. The purpose of this criterion was to have a cross-reference and alternative data collection point in the event that data for the New Attack Submarine system was not available.

a. Reelable Towed Array Handling System (RTAHS)

Based on the above criteria, the choice of the system for analysis was the Towed Array Handling System. This is the system that allows the submarine to stream and retrieve the towed sonar array. The towed sonar array is part of the acoustic sensor suite on board the submarine. The handling system has a cross-section of types of components. They include hydraulics, seawater systems, mechanical cable handling systems as well as control and indicator circuitry and all associated connectors.

The initial intention was to evaluate a system on the New Attack Submarine to identify candidate parts for potential CIM/RAMP manufacture. It was eventually discovered that the system drawings were not fully approved and available for review. The alternative system selected was the similar system on the SEAWOLF submarine. This system is known as the Reelable Towed Array Handling System (RTAHS). During the course of data collection on the SEAWOLF RTAHS, it was determined that the appropriate documentation and drawings were not available to the researcher. This caused data collection to proceed to the second alternate research path, the Reelable Towed Array Handling System (RTAHS) on the LOS ANGELES (688) Class submarine. A review of available drawings and technical manuals and discussions with program personnel confirmed that the system designs were very similar. A complete parts lists was obtained for the LOS ANGELES Class RTAHS. It satisfied the established criteria and became the subject of the CIM/RAMP candidate parts analysis.

b. RTAHS Parts Analysis

The RTAHS has 18 major components. Each major component is comprised of a discrete number of different parts. Some parts appear more than once in each major component. The range of the number of different parts in each major component is between 16 and 345. There is a total of 1975 different parts in the RTAHS system.

The source for each part was provided as a contractor number. A contractor listing was also provided. The contractor list included 57 contractors[4] and three different sets of military or industry standards. Approximately 95 percent of the parts that specified a standard as the source for the part were fasteners.

An analysis was conducted to differentiate between parts that were contractor supplied and those that were in accordance with an established standard. The significance of this data breakdown is that the parts that specify a contractor as the source have the potential to have proprietary design data associated with that part. Conversely, there would be no proprietary data associated with the parts specifying a standard as the source, because they are manufactured to a government or industry standard. According to the analysis, of the total number of parts, 1055 (53 percent) are contractor supplied,

[4] An investigation was conducted into the number of contractors listed who were still in business. The results, although not directly related to the overall investigation, still proved interesting. First an Internet search was conducted. For those not located on the Internet, a telephone directory assistance search was conducted. Of the 57 contractors listed, 49 were located. The search does not preclude that the company was merged or the name completely changed, but the results still suggest some degree of instability in the industrial base.

and 920 (47 percent) are manufactured in accordance with established standards. The results of this analysis are displayed in Table 5.2.

The second analysis was conducted to determine the number of CIM/RAMP candidate parts based on the design data available. The parts were classified into five categories: (1) fasteners, including screws, nuts, bolts, washers, pins, and studs; (2) small mechanical parts (SMPs) that are CIM/RAMP manufacturable; (3) printed wire assemblies (PWAs) that are CIM/RAMP manufacturable; (4) non-PWA electrical parts, including lamps, fuses, microelectronics, and connectors; and (5) other parts, including gaskets, packing, adhesives, and non-CIM/RAMP manufacturable mechanical parts including those from molds or casts. The results of this analysis are displayed in Table 5.3.

The results show that, based on design data alone, 341 are CIM/RAMP manufacturable. The CIM/RAMP manufacturable parts were considered as those classified as PWAs and SMPs. The fasteners, although CIM/RAMP manufacturable, were not included in the total because it was assumed that commercial sources of standard fasteners would likely be available. The 341 CIM/RAMP manufacturable parts equate to 17.3 percent of the parts in the system.

Reelable Towed Array Handling System Parts Analysis			
MAJOR COMPONENT	**# OF PARTS W/ Contractor AS SOURCE**	**# OF PARTS W/ STANDARD AS SOURCE**	**TOTAL # OF PARTS**
CABLE DRIVE UNIT	131	63	194
CABLE DRIVE HYD MOTOR	31	0	31
VALVE STACK ASSBLY	61	15	76
SHEAVE AND CABLE GUIDE	12	4	16
ARRAY FLUSHING AND SNUBBER	37	5	42
HYD CONTROL MANIFOLD	51	51	102
PRESSURE REGULATING VALVE	20	16	36
ON/OFF/BYPASS VALVE	31	12	43
SOLENOID VALVE	48	37	85
CROSS-CONNECT VALVE	16	9	25
CABLE GUIDE/DATA BOX	112	103	215
CABLE STOWAGE/LEVEL WIND	124	52	176
CABLE STOWAGE HYD MOTOR	36	3	39
CABLE STOWAGE HYD BRAKE	18	0	18
CONT & IND (OK-276A/BQ)	98	247	345
CONT & IND (OK-276()/BQ)	134	199	333
CONT & IND (OK-418/BQ)	79	99	178
DIFF PRESSURE TRANSDUCER	16	5	21
TOTAL	**1055**	**920**	**1975**

Table 5.2. RTAHS Parts Analysis: Contractor vs. Standard as the Source.

Reelable Towed Array Handling System Parts Analysis							
MAJOR COMPONENT	FASTENER	SMP	PWA	NON-PWA ELECT	OTHER	TOTAL # PARTS	# CIM/RAMP CAND
CABLE DRIVE UNIT	59	89	0	3	43	194	89
CABLE DRIVE HYD MOTOR	5	11	0	0	15	31	11
VALVE STACK ASSBLY	14	27	0	0	35	76	27
SHEAVE AND CABLE GUIDE	8	5	0	0	3	16	5
ARRAY FLUSHING AND SNUBBER	12	13	0	0	17	42	13
HYD CONTROL MANIFOLD	36	5	0	3	58	102	5
PRESSURE REGULATING VALVE	13	5	0	0	18	36	5
ON/OFF/BYPASS VALVE	16	9	0	0	18	43	9
SOLENOID VALVE	21	11	0	0	53	85	11
CROSS-CONNECT VALVE	5	1	0	0	19	25	1
CABLE GUIDE/DATA BOX	72	40	0	26	77	215	40
CABLE STOWAGE/LEVEL WIND	63	41	0	8	64	176	41
CABLE STOWAGE HYD MOTOR	9	14	0	0	16	39	14
CABLE STOWAGE HYD BRAKE	4	9	0	0	5	18	9
CONT & IND (OK-276A/BQ)	129	11	10	134	61	345	21
CONT & IND (OK-276()/BQ)	111	16	10	124	72	333	26
CONT & IND (OK-418/BQ)	53	2	11	74	38	178	13
DIFF PRESSURE TRANSDUCER	5	1	0	1	14	21	1
TOTAL	**635**	**310**	**31**	**373**	**626**	**1975**	**341**

Table 5.3. RTAHS Parts Analysis: CIM/RAMP Manufacture Candidate Analysis.

C. NAVY INTEREST IN THE APPLICATION OF INTELLIGENT DIGITAL DATA

During the course of this research, 34 individuals were interviewed from the various associated organizations. With the exception of those individuals associated with the RAMP Program, only two individuals interviewed appeared to have a ready understanding regarding the concepts of intelligent digital data, the RAMP Program, and the benefits that the application of this type of technology could provide. The extent of their understanding was measured by the responses to questions posed by the researcher during the interviews. Specifically, the researcher asked questions concerning the application. Then, if necessary, the researcher provided answers in an incremental fashion in order to measure both an understanding of the technology concept as well as an understanding of application and its potential costs and benefits. Only those individuals associated with the RAMP Program thought that the application was one worth pursuing. Four interviewees were quick to point out a specific instance where the application of this technology would not work or would not be cost effective.

One interviewee cited the lack of analysis for the application of intelligent digital data as a reflection of the fact that other initiatives were being explored to achieve the same end. Outsourcing is one of those methods. There have been discussions concerning the potential for a consortium of shipbuilders to take over and operate a portion of the Navy/DLA supply system. These discussions were prompted by the fact that DLA's depot operation cost recovery factors assigned to parts were running "60-70 percent of the procurement cost of the part" (Interview-B, 1997). The potential for including in

procurement contracts a requirement that would make the prime contractor responsible for spare parts for the weapon system in a "just-in-time" delivery scenario has also been discussed (Interview-B, 1997).

No evidence was discovered that the costs and benefits of the application of intelligent digital data to reduce the spare and repair parts inventory had ever been investigated.

D. COSTS OF INTELLIGENT DIGITAL DATA APPLICATION

As mentioned above, no specific cost figures for the procurement of design data were available from any program investigated. This was largely due to the costs of data being deeply embedded in the research and development or overall design contracts (Interview-A, 1997; Interview-C, 1997). No metrics were established or entered in the contract at the time of award to enable tracking or reconstruction of this cost data (Interview-A, 1997). Appendix B details the data that was not available during the course of the research.

The cost data that are available are peripheral to that of design data. Recall the processing cost per contractor drawing for the design contractor for the SEAWOLF Submarine was approximately $5,000 (Interview-A, 1997). The average cost per printed wire assembly to convert hardcopy design data to intelligent digital data is $1,500 (Interview-T, 1997). The cost per part to reverse engineer a printed wire assembly was stated to be part dependent but in all cases higher than the $1,500 average data conversion cost (Interview-T, 1997).

In the absence of specifically documented costs for design data, an alternate method was considered to estimate the value of intelligent digital data. This method involved a spreadsheet-based model to estimate the expected value of the intelligent digital data from the customer's perspective. What would the New Attack Submarine class as an aggregate be willing to pay up front in order to save money over the life cycle of the submarine class. This model is in concert with the purpose of the application of intelligent digital data to reduce the spare and repair parts inventory: make the up-front investment to save money in the long-run.

The function of the model is to calculate a net present value for the difference in the cost of parts procurement between the use of intelligent digital data and existing spare and repair parts inventory procedures. It is an estimation of the net present value of the savings that would result from not stocking the part but not from the cost of the part itself. The annual savings will be considered to be the holding costs. Based on previous analysis (Ahern, 1991), 33 percent of the DLA surcharge is considered as a proxy for accrued holding costs. As previously discussed in Chapter III, the surcharge levied on parts by the supply system varies from fiscal year to fiscal year. The net present value generated by the model would then constitute the upper bound of what the Navy should pay for intelligent digital data for a specific part. This is the upper bound because it equates to the break-even point. If the Navy paid more than this price and if all assumptions and variables' values were valid, the Navy would not recoup the investment over the life cycle of the program. Additionally, this net present value also represents a conservative estimate of the cost savings from this initiative. The net present value represents just the potential

savings in holding costs. It does not take into account the reductions possible in the total inventory as a consequence of the short production lead time as well as contract administrative lead time associated with CIM/RAMP parts.

1. Present Value Model

The present value model was constructed using the *Lotus 1-2-3 Spreadsheet* application. Based on the characteristics and availability of input data, a Monte Carlo simulation could be performed using this same spreadsheet model and the *Crystal Ball* add-in program. For this analysis, the nature of the input data negated the additional benefits that the Monte Carlo simulation could provide. Therefore, the basic spreadsheet net present value model was used. The model calculates the net present value of the difference in purchasing and using intelligent digital data to manufacture inventory when required in lieu of procuring and holding inventory to meet the forecast demand. As mentioned above, the basic function of the model is to calculate a net present value for the differences in the cost of parts procurement between the use of intelligent digital data and existing spare and repair parts inventory procedures. The model and its description are provided as Appendix C.

2. Model Results

The analysis was conducted by altering the three part-specific variables while maintaining all other assumptions and variables constant. The three variables, unit price, failure rate and population per platform, were each changed one at a time. The surcharge

rate although expected to vary from year-to-year was assumed to constant over the life cycle of the program and was assigned as the average of the values from FY-91 to FY-98. The development of the surcharge rate is discussed in more detail in Appendix C.

The analysis was conducted using the three part-specific variables with five point estimate values used for each. The analysis resulted in 125 net present value figures. These figures represent the various combinations of part specific variables. The results of the model are presented in Tables C.1 through C.5. Each table represents the combinations of failure rate and population per platform for a specific unit price.

The unit price of parts with submarine application that are CIM/RAMP manufacturable was believed to range from $1.00 to $90,000.00, with the bulk of these parts in the $2,000.00 to $12,000.00 range (Interview-AJ, 1997). Three intermediate point estimates of unit price were also used, $10,000.00, $1000.00, and $10.00.

The annual failure rates range from four per year to zero. Five conservative point estimates for annual failure rate were selected. Point estimates of 4.0, 1.0, 0.2, 0.1 and 0.033 were used. These failure rates represent four failures per year (or one per quarter), one failure per year, one failure every five years, one failure every ten years and one failure in 30 years.

Population per platform for CIM/RAMP manufacturable parts range from one to 40. The five values used for population per platform were 1.0, 2.0, 5.0, 20.0 and 40.0.

Table C.1 represents the combinations of failure rate and population per platform for the upper bound unit price of $90,000.00. Table C.2 represents the combinations of failure rate and population per platform for a unit price of $10,000.00. Table C.3

represents the combinations of failure rate and population per platform for a unit price of $1,000.00. Table C.4 represents the combinations of failure rate and population per platform for a unit price of $10.00. Table C.5 represents the combinations of failure rate and population per platform for the lower bound unit price of $1.00.

The net present value ranged from $1 (Table C.5) to $503 million (Table C.1). The $1 value represents the most that the Navy should pay for the intelligent digital data for a part that is at the lower bound in terms of unit price, population per platform and failure rate. Conversely, for a part at the upper bound in terms of unit price, population per platform and failure rate, $503 million is the most the Navy should pay. These figures bound the possible.

The other representative point estimate combinations suggest more likely results. The representative point estimate tables (C.2 through C.4) provide a range of $70 to $7 million. These figures also represent a conservative estimate of the potential savings to be experienced by the application of intelligent digital data.

If the the results of the net present value estimation model are used along with the CIM/RAMP candidate parts analysis, a conservative estimate of the potential savings of using intelligent digital data to reduce the spare and repair parts inventory for the New Attack Submarine can be obtained. Recall that 17.3 percent of the parts contained in the Reelable Towed Array Handling System (RTAHS) were candidates for CIM/RAMP manufacturing. For the purposes of this analysis we will assume that the 17.3 percent is an average of the percentages of CIM/RAMP manufacturable parts in each system in the New Attack Submarine.

Recall that the RTAHS is one of 250 such systems on the New Attack Submarine. Since these are all complex systems, we will assume that each contains at least as many parts as the RTAHS; namely 1975 parts.

Although the unit price of parts that are CIM/RAMP manufacturable and found on submarines varies from less than $10.00 to greater than $10,000, suppose we conservatively assume that every part on the New Attack Submarine has a unit price of $10. In addition, suppose averages were used of the resulting combinations of failure rate and population per platform. The average of the values in Table C.4 is $5,070 and would then represent the net present value of the conservative estimate of potential cost savings for each part. With these conservative assumptions the following calculations were made to determine the potential value of the expected life cycle cost savings for the New Attack Submarine:

Life Cycle Cost Savings = (1975 parts/system) x (17.3% of parts) x (250 systems) x ($5,070)

= **$433 million.**

The results of this present value analysis indicate an expected savings in holding costs of $433 million for the population of CIM/RAMP manufacturable parts at an average unit price of $10. This value represents a conservative estimate for the savings of holding costs. As the mix of parts is changed to include parts with a unit price of $100,

$1,000 or $10,000 the savings will increase proportionately. Finally and possibly of greater importance is that the savings figure does not include the reduction in the total value of the inventory because of the reduction in number of parts held as a consequence of the short production lead time associated with CIM/RAMP parts.

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VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY OF THE ANALYSIS

This analysis of the costs and benefits of using intelligent digital data to reduce the spare and repair parts inventory for the New Attack Submarine (NSSN) focused on four elements of the basic question. These elements include: (1) the feasibility of such an application; (2) the need or market for such an application; (3) the Navy's level of interest in such an application; and (4) the costs of the application.

The exploration of the feasibility element included a determination of whether the technology existed to procure design data for the New Attack Submarine in intelligent digital format and then to ascertain whether a vehicle exists to manufacture parts through the use of the intelligent digital data. The discussion in Chapter IV described the methodology used in this investigation. The discussion in Chapter II and the data presented in Chapter V provided a comprehensive overview of both the New Attack Submarine Program history as well as an overview of the Navy's RAMP Program in addressing this element. The need/market element was addressed by both the discussion in Chapter III of the implications for the Navy/DLA supply system as well as the data presented in Chapter V. The level of Navy interest element was addressed in the results of the interview data as well as the design data procurement history presented in Chapter V. The final element concerning the costs of such an application was addressed both in the Chapter III discussion of implications for Navy supply support as well as in the discussion of the data in Chapter V.

The remainder of this chapter presents the conclusions drawn and the recommendations generated from the attempt to conduct an analysis of the costs of using intelligent digital data to reduce the spare and repair parts inventory for the New Attack Submarine. The discussion includes conclusions drawn concerning the technical feasibility of such an application, the need or market for such an application, a measure of the Navy's interest in such an application, and the costs associated with such an application. Recommendations are made concerning future cost/benefit analyses and methods to improve data identification and analysis.

B. CONCLUSIONS

1. Proven Technology

Virtual is a term used in the computer science field to describe the use of computers and digital technology to replicate "in effect or essence though not in actual fact, form or name" (Webster, 1996). The technology to exploit the use of intelligent digital data to reduce the spare and repair parts inventory is real. These capabilities would render a percentage of the Navy/DLA parts inventory as "virtual". These capabilities exist within the Navy and within the defense industrial base. It is the inventory that would exist in effect though not in actual form until required.

The technology of applying intelligent digital data to reduce the spare and repair parts inventory has been proven by the Navy's RAMP Program. This program has taken intelligent digital data for required parts and manufactured those parts in a timely and cost-effective manner. The RAMP Program developers assumed adequate technical data were

available on spare parts to be able to create a parts specification data base. Not only did this assumption prove false, the lack of accurate design data for the required parts persists. However, with some analysis and forethought, this problem can be avoided for current and future weapon systems under procurement.

The design, manufacture, and support of systems have become more closely related. The CATIA CAD/CAM application and associated database is just one example. CATIA is not just a shipbuilding CAD/CAM application. It has been used by Boeing Corporation in its design and manufacture of the Boeing 777 Aircraft, and on a smaller scale by at least one Formula One racing team (IBM/Dassault, 1997). CATIA has demonstrated the technical capability to provide intelligent digital data.

Using the relationship between design, manufacture, and support is one potential means to obtain more efficient and effective logistic support. It is possible that "virtual" inventory may provide the best balance between cost-effectiveness and timely response.

2. A Market Exists for the Application

There is a market for the application of intelligent digital data to the spare and repair parts inventory for the New Attack Submarine. The need to procure limited quantities of the expensive, no-longer-available parts that fostered the genesis of the RAMP Program is the same need that the Navy should be seeking to satisfy by pursuing the application of intelligent digital data to the Navy's inventory in general and, specifically, to the New Attack Submarine. The United States Air Force's next-generation air superiority fighter aircraft, the F-22, has just made its first flight but is already on the

verge of carrying out-of-production parts. This situation has already cost the Air Force $76 million in aircraft redesign and obsolete parts procurement. (Evers, 1997)

The primary consideration in the decision to acquire design data has been whether or not further production will be conducted using competitive bids. Future logistic support has not been a major consideration in the acquisition decisions concerning design data. Historical data concerning program life cycle costs indicate that two-thirds of the life cycle cost of a weapon system are a result of operations and maintenance costs (Walls, 1997). These data suggest that logistic support should be a consideration when weighing the decision to acquire design data.

The stability of the industrial base is another factor that must be considered when analyzing the market for this application. The defense industrial base has changed dramatically in the past decade. Mergers, acquisitions, and overall consolidation have been the trend in the defense industry since the end of the Cold War.

As a consequence of the industrial base instability, companies which currently constitute the defense related industrial base may at some future time merge, be acquired, go out of business, or change their business focus to other than defense related products. The end result is the company that makes Widget A for System X may not be around in the year 2008 or 2018 to make a replacement Widget A. This is a void intelligent digital data can fill. By taking steps during the design and initial production of a weapon system to include intelligent digital data as a future source of spare parts, the resulting logistic support over the long term can be more responsive and less expensive.

The analysis conducted in Chapter V suggests that there does exist a population of parts in the New Attack Submarine that are candidates for manufacturing in an intelligent digital data environment. The analysis was conducted on one of the approximately 250 systems which comprise the New Attack Submarine. The analysis indicates that 17.3 percent of the parts listed for that system are candidates for manufacturing using intelligent digital data. This population includes both mechanical parts and printed wire assemblies. By combining the CIM/RAMP candidate parts analysis with the intelligent digital data value model, a conservative estimate of potential savings of $503 million was obtained for a population of $10 parts over the life of the New Attack Submarine class. The more expensive the population of parts the greater the savings. This analysis only accounts for the savings in holding costs. It does not account for the savings to be realized in the reduction in physical inventory. Recall, however, that the Navy's 1996 inventory value was estimated to be $33.7 billion (GAO/NSIAD-97-47) and that the DOD's annual inventory maintenance costs were running approximately 33 percent of the inventory value in 1995. These figures are large enough that even a small percentage reduction in inventory would result in significant savings as capital is no longer required to be invested in inventory and the lower inventory levels will reduce the overall maintenance costs of the inventory.

Intelligent digital data are not being procured for the New Attack Submarine. As stated in Chapter V, only Level II design data are being procured. Level II design data are not suitable for CIM/RAMP manufacturing. The Level III design data that might be available have been purchased for previous classes of submarines for equipment also

installed in the New Attack Class. These data would require conversion to intelligent digital format.

3. Navy Interest in the Application of Intelligent Digital Data

The data gathered for this thesis indicate that submarine program personnel are not actively pursuing the application of intelligent digital data to the spare and repair parts inventory. There are at least eight reasons why this lack of interest persists.

a. There is limited knowledge of the technology and its potential for application. Of the 20 individuals interviewed outside the RAMP Program 18 demonstrated a lack of understanding or a misunderstanding of the benefits that intelligent digital data provide. The individuals interviewed either had no knowledge of intelligent digital data, the RAMP Program, or their understanding of the purpose of each was in error.

b. "Economic reality" is a factor in the interest shown to this application. Design data have the potential to be costly (Interview-B, 1997). This application requires an up-front investment for a long-run payoff. The investment is made early in the system life cycle to realize savings years into the life cycle. Consider the example of the New Attack Submarine. The contract to procure the lead ship of the New Attack Class is to be signed in FY-98. If the data acquisition strategy was changed to selectively acquire intelligent digital data, then funds would be earmarked for acquisition

of design data with each platform procured. Recall, the lead ship is scheduled to begin construction in FY-98 with additional hulls planned for procurement in FY-99, FY-01, and FY-02. Lead ship delivery in FY-04 and attainment of initial operational capability in FY-06 would begin the recoupment of the investment by realizing savings in the cost of repair parts. The investment would continue as each new hull is procured (approximately one hull per year) until the desired amount of design data is procured. The potential for accruing savings is increased each time another hull is delivered. It is unlikely, however, that substantial savings will be realized immediately, but rather would accrue over time.

c. The savings are realized in different "pots" of money than the one from which the investment originated. Additionally, the savings are realized by different organizations than the one which made the investment, with a time disparity of up to 50 years. This 50-year span is from the time the first hull enters service until the time the last hull leaves service. There is no apparent immediate reward to provide an incentive for one organization to save money for another organization. For example, for the New Attack Submarine, the funding for the acquisition of the design data if pursued would originate in the research, development, test and evaluation (RDT&E) and shipbuilding and conversion Navy (SCN) appropriation accounts of the program office beginning in FY-98. The savings would be realized in the operations and maintenance Navy (O&MN) appropriation accounts of the major operational commands sometime after FY-06. The question becomes, who should be the watchdog? Should it be the Assistant Secretary of the Navy, Financial Management and Comptroller (ASN(FM&C))? It can be argued that because

this application involves the weapon system acquisition community and sponsors, the logistics community, and the financial management community both at the ASN level as well as the fleet level, they should all be involved in the decision-making and oversight process.

d. Automation in general is a job-threatening technology. There are few incentives for someone in a threatened position to embrace a technology that could cause that same person to look for new employment. A "virtual" inventory would not demand the same level or type of maintenance that an actual inventory would demand. This would be especially true in the procurement area of supply support. One of the benefits that intelligent digital data provide is a reduced procurement lead time. The administrative lead time for obtaining a contract with a contractor is part of this time. That time can be expected to be significantly reduced as this process becomes more automated. It can, therefore, be assumed that some jobs in the procurement area of supply support might be threatened. The tradeoff of saving money for the organization versus reduced potential for continued employment in that organization is a difficult one, and one which appears to contribute to the Navy's lack of interest in applying intelligent digital data to reduce spare and repair parts inventories.

e. No attempt to quantify a cost/benefit analysis of such an application, even on a small scale has been identified. With the exception of anecdotal data, no cost figures for design data were discovered. The cost of design data is crucial to

any cost/benefit analysis conducted. Without quantified costs and benefits to debate, there is limited opportunity to generate interest.

f. There are other methods to achieve the same end. Outsourcing is one of those methods. There have been discussions concerning the potential for a consortium of shipbuilders to take over and operate portions of the Navy supply system. These discussions were prompted by the fact that DLA's depot operation cost recovery factors assigned to parts were "running 60-70 percent of the procurement cost of the part" (Interview-B, 1997). The potential for including in procurement contracts a requirement that would make the prime contractor responsible for spare parts for the weapon system in a "just-in-time" delivery scenario has also been discussed (Interview-B, 1997).

g. It is easier to identify parts that definitely cannot be CIM/RAMP manufactured than those that can. During the interview process, there was more effort expended by the interviewees in pointing out particular components that could not be participants than in analyzing for those that could. At least three interviewees pointed out examples of components that would not be well suited for the application of intelligent digital data. Submarine components that have special sound-quieting standards were mentioned on at least two occasions. (Interview-B, 1997; Interview-F, 1997).

h. Identification of those parts that can be manufactured using CIM/RAMP technology is a difficult task. It requires more than just analyzing lists of

stock codes. A 1988 study performed by a contractor for NAVSUP investigated whether there was standard nomenclature or data which could identify parts as candidates for the RAMP Program and therefore establish a database for both the NAVICP RAMP liaison personnel and the inventory managers. No easy method could be found purely from stock number and nomenclature. A review of over 87,000 parts identified that only 0.6 percent could be determined to fit into the RAMP technology using just the stock number and part nomenclature (Peterson, 1993).

The analysis documented in Chapter V required screening of part lists to eliminate obvious non-candidate parts and reference to at least Level II design data to establish a candidate list. There is no method for identifying these parts initially or retrospectively from established engineering or logistics codes or numbering systems. In the absence of design data, the determination of whether the part is CIM/RAMP manufacturable must be made by the physical examination of the part by manufacturing technicians familiar with the process. However, physical inspection is not always possible. Additionally, if the design data are not available, then the part must be reverse engineered to obtain it. The reverse engineering process increases both cost and procurement lead time for the part.

4. Costs

The key component to evaluation of the cost of applying intelligent digital data to reduce the spare and repair parts inventory is the cost of the design data in digital format. The key component of that cost is the cost of the design rights. Design-data-rights cost

data were not available. The other components, although unavailable in this analysis, could with proper access be determined. These other components are cost of processing the design data and producing it in intelligent digital format, as well as maintaining the cost of the database of design data. Although design data have been obtained in the past, the necessary metrics for calculating costs have never been included in the contracts which required the furnishing of design data as an end product. These costs remain imbedded in the contracts and are not identifiable as attributable costs.

The desired design data costs could be prohibitive. This would be due to the proprietary nature of the data within industry and the unwillingness of the industry leader to forfeit without appropriate compensation the "edge" which it holds over its competitors. Another reason for the cost prohibitive nature of the data is that the data can be used as a hedge against the volatile nature of large dollar value defense program contracts. The drastic reductions in the SEAWOLF Program were discussed in Chapter II. An example of a cancellation of a major weapons acquisition program is the Navy's A-12 Attack Aircraft. This program was approved in 1984 with a full-scale development contract signed in 1988 for approximately $4 billion. The A-12 program was subsequently canceled in 1991 without the production of a single airframe (DSMC, 1996). These program changes have made contractors very wary of being left "holding the bag" for the program startup costs with little hope of accruing future profits. It is exactly these experiences that cause the price tags assigned to design data in new programs to be significantly "marked up". This is done as a hedge against program cancellation and to assure a future income stream.

The net present value model for estimating the value of intelligent digital data presented in Chapter V and Appendix C provides a reasonable estimate for this purpose. A second method to estimate the value of the data could also be used. This method would involve estimating the cost of reverse engineering the part. Simply, the Navy should pay no more for intelligent digital data for a part than it would cost the Navy to reverse engineer the part to obtain intelligent digital data using existing RAMP technology. The cost of reverse engineering the part has two major variables, complexity and documentation available. A proposed method for reverse engineering cost estimation is provided as Appendix D.

C. RECOMMENDATIONS

1. Develop a method for more easily identifying parts that can be manufactured in an intelligent digital data environment and provide a method for identifying the parts for which the design data have been obtained in intelligent digital format.

2. Conduct cost/benefit analyses of applying intelligent digital data to reduce inventory requirements for all new weapon systems under procurement. The analysis should determine the parts which are manufacturable in an intelligent digital data environment. The analysis should also examine demand characteristics for the manufacturable parts. The cost of the design data should be investigated. Rather than

inquiring about all the design data or even entire systems, the investigation should focus on parts that can be manufactured. Additionally, estimates should be obtained to gauge the cost of manufacturing the parts when needed. These cost data should be compared to the cost data for maintaining the inventory in the absence of intelligent digital data. Using the demand characteristics for these parts, a cost difference analysis similar to that conducted for wholesale inventory stocking should be performed. The analysis would indicate which parts should continue to be stocked, which parts should not be stocked but dedicated to CIM/RAMP manufacturing, and which parts should not be stocked or dedicated to CIM/RAMP manufacturing. Selective purchasing of design data may prove to be the most cost-effective method. The evaluation would represent a net present value analysis of the expected future savings in inventory maintenance costs versus the design data procurement costs and the costs of manufacturing parts when needed.

3. The process of procuring intelligent digital data should include procedures for validation of the data as complete and accurate. This should be done regardless of whether the data are intended for future new systems procurement competition or for logistic support of existing systems. Consideration should be given to incorporating a provision for technical assistance from the developer should problems arise during the attempted use of the design data.

4. The RAMP Program should prepare a method for estimating the cost of reverse engineering parts. The method should expand on the basic structure provided as Appendix D.

APPENDIX A. TRANSITION TO DIGITAL ENVIRONMENT

PRINCIPAL DEPUTY UNDER SECRETARY OF DEFENSE

3015 DEFENSE PENTAGON
WASHINGTON DC 20301-3015

ACQUISITION AND TECHNOLOGY

JUN 4 1996

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMEN, JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
DIRECTOR, DEFENSE RESEARCH AND ENGINEERING
ASSISTANT SECRETARIES OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
DIRECTORS, DEFENSE AGENCIES

SUBJECT: Acquisition of Information in Digital Format

The acquisition of data in digital format offers numerous benefits to the Department, most which translate directly into cost savings. To take full advantage of these benefits, I ask you to ensure your existing contracts are reviewed for data delivery format and, where non-digital formats are specified, that you modify your contracts to require digital format when it is mission-effective and cost-effective to do so.

Many existing contracts pre-date digital requirements and specify data delivery on paper, aperture cards, and microfiche. More often than not, these may be changed to digital format with no loss in customer suitability and security, and with all of the accompanying gain in supportability and cost savings. Naturally, changes to digital format must be compatible with Government information processing systems, but contractor data systems and formats should be used whenever they satisfy program needs.

I realize many agencies have already begun moving in this direction, but to gain speed and consistency I believe we should pursue a more formal effort. Please communicate this to your program managers and contracting officers. Monitor their progress and give them your enthusiastic support---this is a good source of savings and efficiency.

R. Noel Longuemare

Figure A.1. Principal Deputy Under Secretary of Defense (Acquisition and Technology) Memorandum

COMPTROLLER

UNDER SECRETARY OF DEFENSE
1100 DEFENSE PENTAGON
WASHINGTON, DC 20301-1100

MAY 21 1997

MEMORANDUM FOR UNDER SECRETARIES OF DEFENSE
DIRECTOR, DEFENSE RESEARCH AND ENGINEERING
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE
INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
ASSISTANTS TO THE SECRETARY OF DEFENSE
DIRECTOR, ADMINISTRATION AND MANAGEMENT
DIRECTORS OF THE DEFENSE AGENCIES
DIRECTORS OF THE DOD FIELD ACTIVITIES

SUBJECT: Management Reform Memorandum #2 -- Moving to a Paper-free Contracting Process by January 1, 2000

The Secretary of Defense has directed that we undertake a revolution in business practices in conjunction with the Quadrennial Defense Review. He has specifically cited the need to simplify and modernize our acquisition process in the area of contract writing, administration, finance, and auditing.

In order to determine the feasibility of sweeping changes in this area, I am requesting the Under Secretary of Defense (Acquisition and Technology) to develop, by July 1, the blueprint of a plan to move to a totally paper-free contract writing, administration, finance, and auditing process. This plan should be coordinated with all of the organizations that participate in the integrated process. The plan should incorporate the Department's ongoing initiatives for use of purchase cards, electronic catalogues, electronic commerce and imaging.

I request your full cooperation in developing this blueprint.

In approximately two weeks from the date of this memorandum, I will have my secretary arrange for a meeting with the USD(A&T) to obtain a status on how this effort is proceeding.

John Hamre

John J. Hamre

cc: Secretaries of the Military Departments
Chairman of the Joint Chiefs of Staff

Figure A.2. Under Secretary of Defense (Comptroller) Memorandum

UNDER SECRETARY OF DEFENSE
1100 DEFENSE PENTAGON
WASHINGTON, DC 20301-1100

COMPTROLLER

JUL 29 1997

MEMORANDUM FOR UNDER SECRETARIES OF DEFENSE
DIRECTOR, DEFENSE RESEARCH AND ENGINEERING
ASSISTANT SECRETARIES OF DEFENSE
GENERAL COUNSEL OF THE DEPARTMENT OF DEFENSE
INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
ASSISTANTS TO THE SECRETARY OF DEFENSE
DIRECTOR, ADMINISTRATION AND MANAGEMENT
DIRECTORS OF THE DEFENSE AGENCIES
DIRECTORS OF THE DOD FIELD ACTIVITIES

INFO COPY: SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF

SUBJECT: Addendum to Management Reform Memorandum #2 -- Moving to a Paper-free Contracting Process by January 1, 2000

Management Reform Memorandum #2 cited the need to simplify and modernize our acquisition process in the area of contract writing, administration, finance and auditing.

After further review, it has been determined that in order to achieve successful implementation in this area, the logistics community needs to be included in this effort. Therefore, through this addendum, I am now asking that a plan be developed to move to a totally paper-free acquisition process.

The paper-free acquisition process coincides with the Department's corporate goal of digital operations for acquisition management and life cycle integrated information. The paper-free plan will define a process whereby electronic information can be managed, accessed, and shared by all users.

John J. Hamre

Figure A.3. Addendum to Under Secretary of Defense (Comptroller) Memorandum

THE DEPUTY SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-1000

JUL 2 1997

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN, JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
DIRECTOR, DEFENSE RESEARCH AND ENGINEERING
ASSISTANT SECRETARIES OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
DIRECTORS, DEFENSE AGENCIES

SUBJECT: Policy for the Transition to a Digital Environment for Acquisition Programs

The Department has made substantial progress in the acquisition, management, and use of digitized information. It is now time to move forward to a fully digital environment in all acquisition program and support offices. Industry has already demonstrated that this is not only possible, but preferable to traditional paper-driven systems. I am setting a corporate goal of digital operations being the method of choice for all acquisition management and life cycle support information. By the end of 2002, the overwhelming majority of DoD acquisition and logistics operations should be based on digital methodologies and products.

The focus of this effort must be at the program office level. Consistent with the architecture established by the joint DoD level executive steering group, Program Managers shall be responsible for establishing a data management system and appropriate digital environment that allows every activity involved with the program throughout its total life-cycle to exchange data digitally.

I am counting on your support for this critical initiative that will enhance acquisition reform, further empower our Integrated Product Teams, and combine with electronic commerce to achieve greater efficiencies in the weapon system life cycle.

Figure A.4. Deputy Secretary of Defense Memorandum

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-3010

ACQUISITION AND TECHNOLOGY

JUL 15 1997

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN, JOINT CHIEFS OF STAFF
UNDER SECRETARIES OF DEFENSE
DIRECTOR, DEFENSE RESEARCH AND ENGINEERING
ASSISTANT SECRETARIES OF DEFENSE
DIRECTOR, OPERATIONAL TEST AND EVALUATION
DIRECTORS, DEFENSE AGENCIES

SUBJECT: Guidance for the Transition to a Digital Environment for Acquisition Programs

In his July 2, 1997 memorandum entitled "Policy for the Transition to a Digital Environment for Acquisition Programs," the Deputy Secretary of Defense set a corporate goal of digital operations being the method of choice across our community by the end of 2002. He further stated that the overwhelming majority of DoD acquisition and logistics operations are expected to be based on digital methodologies and products by that time. I strongly support the Deputy Secretary of Defense in this critical initiative.

To enable the smooth implementation of the Secretary's policy, the Director, Acquisition Program Integration, shall augment the Integrated Program Management Initiative Executive Steering Group (IPMI ESG) with representatives experienced in implementing a digital environment. As a minimum, the Service Acquisition Executives, Assistant Secretary of Defense for Command, Control, Communications and Intelligence, and Deputy Under Secretary of Defense for Logistics will be represented. The ESG will coordinate cross Component activities, develop any additional guidance deemed necessary for achieving digital program office operations and report progress, to the Defense Systems Affordability Council.

Attachment (1) provides the additional implementation guidance which was originally coordinated with the policy memorandum.

Noel Longuemare

R. Noel Longuemare
Acting Under Secretary of Defense
(Acquisition and Technology)

Attachment:
As stated

Figure A.5. Under Secretary of Defense (Acquisition and Technology) Memorandum

TRANSITION GUIDANCE

ACQUISITION PROGRAMS DIGITAL ENVIRONMENT

In order to achieve a digital environment in acquisition programs, the following specific guidance is provided:

a. The Executive Steering Group shall report progress to the USD(A&T) every six months. The first progress report shall include a Plan of Action and Milestones for this initiative.

b. Each component shall provide budgetary and technical support to their program managers to attain an acquisition program digital environment.

c. The Components and Defense Contract Management Command (DCMC) shall encourage contractors to submit concept papers under the single process initiative (SPI) to promote and define the digital environment and reduce the opportunity for the development of sub-optimized solutions by each program office.

d. The Defense Acquisition University (DAU) shall ensure that, beginning in FY 98, program management training courses include in their curriculum guidance on the practical implementation of the digital environment.

e. All new programs will include digital operations in their strategy planning. All existing programs shall complete a feasibility and cost assessment of moving to digital operations as soon as possible. This requirement will be reflected in appropriate Component budgets.

f. The feasibility and cost assessments for ACAT I programs will be completed in sufficient time to support budgeting no later than the FY00 POM.

g. The data formats of independent standards-setting organizations shall take precedence over all other formats. The issue of data formats and transaction sets shall be independent of the method of access or delivery of the data.

h. Existing infrastructure shall be used in implementing the digital environment to the maximum extent practicable.

i. Milestone Decision Authorities shall assess the digital environment developed for each acquisition program as required by DepSecDef policy.

Figure A.6. Attachment to Under Secretary of Defense (Acquisition and Technology) Memorandum

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

17 JUL 1997

ACQUISITION AND TECHNOLOGY

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE (ACQUISITION & TECHNOLOGY)
UNDER SECRETARY OF DEFENSE (COMPTROLLER)
ASSISTANT SECRETARY OF DEFENSE (COMMAND, CONTROL, COMMUNICATIONS & INTELLIGENCE)
DEPUTY UNDER SECRETARY OF DEFENSE (ACQUISITION REFORM)
DIRECTOR, ACQUISITION PROGRAM INTEGRATION
DIRECTOR, DEFENSE PROCUREMENT
DIRECTOR FOR ADMINISTRATION

SUBJECT: Life-Cycle Information Integration

The Secretary of Defense has directed that we undertake a revolution in business practices in conjunction with the Quadrennial Defense Review. We have begun this process with the recent Deputy Secretary of Defense policy to migrate acquisition and logistics operations to digital methodologies and products by 2002. Our goal is to establish an environment that allows every activity involved with a program throughout its life-cycle to benefit from integrated information, and electronic data interchange.

The increasing complexities and interdependencies of acquisition and logistics systems integration requires a dedicated, synergistic effort to address issues of information integration, and shared data throughout the weapon system life cycle. To provide a dedicated and focused management of these life cycle processes which are heavily dependent on integrated shared data; I am hereby consolidating the Continuous Acquisition and Life-Cycle Support (CALS), Logistic Business Systems (LBS) and Electronic Commerce/Electronic Data Interchange (EC/EDI) offices into a Life-Cycle Information Integration Office under the leadership of Mr. Mark Adams. Mr. Adams will be responsible for coordinating personnel realignments, funding resources, budget issues, contracts, office facility needs and all other mission requirements.

John Phillips

John F. Phillips
Deputy Under Secretary of Defense (Logistics)

Figure A.7. Deputy Under Secretary of Defense (Logistics) Memorandum

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APPENDIX B. SUMMARY OF DATA NOT AVAILABLE

Throughout the investigation, a number of data important to the analysis were determined to be not available. This appendix details data not available and the reason the data were not available. The purpose of this appendix is provide students conducting thesis research on similar or follow-on topics with a record of both the data obtained as well as that which was not available.

A. DESIGN DATA COST.

1. Data and Significance

No documented cost figures were available from either the New Attack Submarine Program or the SEAWOLF Program for any specific equipment installed or expected to be installed on those platforms. The costs are believed to have two major components, proprietary data rights and data processing costs.

2. Reason not Available

The necessary metrics have not been incorporated in contracts to document these costs. Although design data has been procured, the specific costs of that design data have been entwined with multiple line items in research and development contracts and weapon system procurement contracts.

B. VALUE OF SPARE AND REPAIR PARTS INVENTORY

1. Data and Significance

Neither the value of the spare and repair parts inventory supporting the submarine force nor the value of the inventory supporting a specific class of submarine could be determined. These data would have been useful in determining the potential savings for intelligent digital application.

2. Reason not Available

These data were not available because NAVICP and DLA don't view inventories as platform specific for ships. In addition, certain parts have the potential to support a number of different weapon systems. There does not appear to be a good method of querying the computer systems, which have the status of the wholesale inventory, to receive an accurate answer. If a query was initiated using all active submarine Unit Identification Codes (UICs) this would determine the existing inventory that is submarine applicable. This answers the question of what is the value of the portion of the wholesale inventory that has submarine application. The problem arises in that it also includes items that are also found on other platforms. Trying to apportion how much of each item supports which weapon system would be a time consuming task and the accuracy of the results would be questionable.

C. REVERSE ENGINEERING COSTS

1. Data and Significance

Reverse engineering cost estimates or examples were not available. The reverse engineering cost estimates would have been helpful in determining the maximum price to pay for intelligent digital data. These data could be used in the construction of a model to estimate the cost of reverse engineering based on the part characteristics as they apply to the reverse engineering process. Such a model is proposed in Appendix D. If the Navy can reverse engineer the part and obtain the intelligent digital data for X dollars then X dollars is the maximum price the Navy should pay for intelligent digital data from the contractor.

2. Reason not Available

The data were not available from the RAMP Program or RAMP facilities. It is unclear whether the data were never recorded or whether it was not broken out of the entire production package cost.

D. SPECIFIC COST SAVINGS EXAMPLES FOR RAMP APPLICATION

1. Data and Significance

Specific cost savings examples for a specific part or series of parts were not available from the RAMP Program. Some general savings figures were available, but

most took the form of percentage savings and efficiency increases. There were very few dollar value examples of RAMP Program savings potential. These examples are important in establishing credibility in the program that has been in operation producing parts for seven years. These data are important on a small scale to gage the magnitude of potential savings when applied on a larger scale.

2. Reason not Available

The data were not available from the RAMP Program, NAVICP or RAMP facilities. It was unclear whether the data was not recorded, not broken out of the overall production package or whether the other option (i.e., contract for procurement with other than RAMP facility) was not investigated or just did not exist.

E. DEFENSE LOGISTICS AGENCY SURCHARGE RATE

1. Data and Significance

The DLA surcharge rates for consumable items were requested for fiscal years 1990 through 1998. The data were desired to validate several statements by interviewees on the "cost of doing business with DLA", as well as for use in the spreadsheet-based net present value model.

2. Reason not Available

The data were requested from the Defense Logistics Agency. The request was acknowledged but denied as the data was considered proprietary and not normally disseminated outside the agency (DLA).

F. SUMMARY

The investigation proved very challenging from the aspect of locating the data desired to analyze the costs of the application of intelligent digital data. Despite the qualitative evidence suggesting the application makes good fiscal sense, it proved difficult to translate into quantitative terms. In discussing this qualitative to quantitative translation the thesis sponsor related the following point:

> Why do you think we ask graduate school thesis students to take on these thesis topics? If the data were readily available we could do the cost/benefit analysis ourselves. (Interview-H, 1997)

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APPENDIX C. NET PRESENT VALUE ESTIMATION MODEL

A net present value estimation model was constructed using the Lotus 1-2-3 Spreadsheet Application. Analysis was conducted using the model to calculate the net present value of the benefits of purchasing intelligent digital data to reduce the spare and repair parts inventory of New Attack Submarine for a variety of parts with varying characteristics. This valuation process was conducted from the customer's perspective. What is the most the customer would be willing to pay for the intelligent digital data based on the forecast savings from not accruing holding costs prior to actually needing the part over the life cycle of the weapon system?

The basic function of the model is to calculate a net present value for the differences in the cost of parts procurement to the customer between the use of intelligent digital data and current spare and repair parts supply procedures. It is an estimation of the net present value of the savings that would result from not stocking the part. The annual savings will be considered to be the holding costs (storage, transportation, obsolescence, loss/damage, and investment costs). For the purposes of this estimation, a percentage of the surcharge is considered as a proxy for accrued holding costs. As previously discussed in Chapter III, the surcharge levied on parts by the supply system historically has varied from fiscal year to fiscal year.

A. MODEL DEVELOPMENT

The construction and functioning of the net present value model is described in the following paragraphs. Table C.6 provides an example of the model output for a $10,000.00 unit price, 20 parts per platform and a failure rate of one per year.

1. Fiscal Year

The fiscal year is used to anchor the model to the New Attack Submarine Program in terms of a fiscal year calendar. Funding for the first New Attack Submarine is contained in the Fiscal Year 1998 Defense Appropriations Act. However, The first submarine will not enter service until FY-04. Costs are assumed to occur at the end of the year.

2. Year

The year is simply the sequential year of the program. Year zero is considered to be FY-98. This is the fiscal year which the government is about to enter and coincidentally the fiscal year in which funding for the first New Attack Submarine has been appropriated. This number is used in the net present value calculation as well as the inflation calculation.

3. Submarines in Service

The number of submarines in service is calculated by adding together the number of platforms which have achieved operational capability. The schedule of contract awards

was obtained from *The Integrated Logistics Support Plan for the New Attack Submarine* (PEO SUB-X, 1993) as well as from the FY-98 President's Budget (OMB, 1997). The first hull is scheduled to be delivered in FY-04 (PEO SUB-X, 1993; OMB, 1997). For the purposes of the model the first four platforms are assumed to take the same amount of time to be delivered (six years from contract award) (PEO SUB-X, 1993). The next four platforms are considered to reach operational capability in five years from contract award (Moore, 1997). The remaining 22 platforms are considered to reach operational capability in four years from contract award (Moore, 1997). The class size is programmed to be 30 platforms. Each platform is assumed to have a 30-year life cycle from delivery. Beginning with the contract awards for hulls nine through 30, the construction rate is expected to increase to 1.5 hulls per year. For the purposes of this model it is assumed that two hulls will be delivered in the odd fiscal years beginning with FY-13 and one hull will be delivered in the even fiscal years beginning in FY-14. This pattern is assumed to continue to class completion in FY-27.

4. Population per Platform

The basic functioning of the model requires an estimate of the total population of a part within the New Attack Submarine class. The total population is the number of times the part appears throughout the New Attack Submarine class. In order to estimate the total parts population a population of the part per platform is needed. The population per platform is a specific characteristic of the part. The population per platform is the number of times the part in question appears throughout one hull of the New Attack Submarine.

The population per platform was a variable in the model that was assigned different values during different runs of the model.

5. Total Population During the Year

The total population during the year is simply the number of submarines in service during a year multiplied by the population per platform.

Total Population During the Year = (Submarines in Service During the Year) x (Population per Platform).

6. Part Failure Rate

The part failure rate (number of times a part fails per year) is the predicted failure rate of the part in a particular weapons system. It is assumed to be the average over all weapon systems using the part. The failure rate is a specific characteristic of the part. The failure rate was also a variable that was assigned different values during different runs of the model.

7. Part Demand

Part demand during a year is the predicted total annual failure rate of the part during that year. It is the product of the part's failure rate and the total population of the part. This is the demand for the part which must be met by the supply system.

Demand During a Year = (Failure Rate) x (Total Population During the Year).

8. Inflation Factor

The inflation factor is used to adjust the price of the part in accordance with inflation. In accordance with the guidance of the *Office of Management and Budget (OMB) Circular Number A-94* and the economic assumptions of the *Budget of the United States Government, Fiscal Year 1998,* inflation for this model is assumed to be 2.7 percent per year. The inflation factor is calculated by the following formula:

$$\textit{Inflation Factor} = (1 + i)^{n} \;;$$

where: i = ***inflation rate, and***
n = ***the number or years.***

9. Unit Price

The price is the procurement price of the part (i.e., what the supply system pays the manufacturer for the part). The price is adjusted for inflation beyond year zero. The price is a specific characteristic of the part. The price is a variable in the model that can be modified during different runs of the model.

10. DLA Surcharge

The DLA surcharge is the charge which the DLA Depot levies on top of the procurement price of the part to recover the holding costs and other overhead costs associated with the depot. The surcharge is calculated by multiplying the unit price by the surcharge rate. The surcharge is a variable that can change each fiscal year. The purpose

of the surcharge is to replenish the Navy Working Capital Fund (NAVICP) or Defense Working Capital Fund (DLA Depot) corpus for the costs incurred in maintaining the spare and repair parts inventory. The surcharge history for NAVICP was presented in Chapter III.

DLA Surcharge = (Unit Price) x (Surcharge Rate).

11. Annual Costs from Inventory

The annual costs from inventory is the product of multiplying the annual demand times the sum of the unit price plus the surcharge. This figure represents the cost of the part from the current supply system in the absence of intelligent digital data.

Annual Costs From Inventory = (Part Demand) x [(Unit Price) + (DLA Surcharge)].

12. Annual Costs from Data

The annual costs from data represents the annual costs of obtaining parts using intelligent digital data. The CIM/RAMP manufactured parts do not accrue holding costs. Therefore, the annual costs from data is the product of the annual demand and the sum of the unit price plus the portion of the DLA Surcharge not attributable to holding costs. Recall from previous analysis (Ahern, 1991), that holding costs represent approximately 33 percent of the DLA surcharge. Holding costs are assumed to be eliminated when parts are designated for CIM/RAMP manufacturing versus being maintained in inventory.

Therefore, the cost of a part from data (i.e., designated for CIM/RAMP manufacturing) then becomes the unit price of the part plus the remaining portion of the DLA surcharge (1-.33=.67 or 67 percent) that accounts for the cost of doing supply management business other than holding costs. This is assumed to be a valid cost for RAMP as well as DLA.

Annual Costs From Data = (Part Demand) x {[(Unit Price) + [(.67) x (Surcharge)]}.

13. Annual Difference in Costs

The annual difference in costs is the difference between the annual costs from inventory and the annual costs from data.

Annual Difference in Costs = (Annual Costs From Inventory) - (Annual Costs From Data).

14. Net Present Value

The net present value term represents the net present value of the total annual differences in costs over the life cycle of the New Attack Submarine class. This term is an estimate of the value of the intelligent digital data for the part under the stated conditions.

B. CONCEPTUAL FRAMEWORK OF MODEL DEVELOPMENT

The model was constructed to from the theoretical framework of separately determining the annual costs of the two alternative parts source methods. From these

annual costs an annual differences are determined and a net present value of the annual differences is calculated. The assumption made concerning the calculation of the holding costs could have allowed the model as presented to be simplified. Because the two cost alternatives are calculated using the same variable it is not necessary to calculate the costs of each alternative part source. The model could easily have been simplified to a calculation of the annual holding costs and a net present value of those annual holding costs. The model was presented in the longer form to allow for follow-on investigation using different methods for calculating the annual costs from inventory and from data, where the variables for each cost calculation may not be the same. The model is was not simplified because it was thought to be worthwhile to view it in its conceptual form.

C. VALUES ASSUMED FOR VARIABLES IN THE MODEL

1. Part Specific Characteristics

a. Population per Platform

The population per platform is used in the basic functioning of the model to calculate the total population of the part within the New Attack Submarine class. Five values were assigned to this variable during the analysis, one, two, five, 20, and 40. The values selected are an upper and lower bound as well as three representative intermediate point estimates. The point estimates represent a low population value, three median population values, (i.e., the part appears several times within the same system in the

submarine, or once in several different systems in the submarine), and a large population value (i.e., part appears several times within several different systems in the submarine). (Interview-B, 1997; Interview-AC, 1997; NAVSEA, 1993)

b. Failure Rate

The values chosen for failure rate (failures per year) ranged from 4.00 to .033. These bounds represent four failures per year (one per quarter) and one failure in 30 years. The upper bound of four failures per year was considered to be the worst acceptable predicted failure rate (Interview-AH, 1997). The lowest predicted failure rate for a part is zero. However, in order to quantify a lower bound, one failure in 30 years or 0.033 failures per year was chosen. Thirty years is the expected life cycle of each New Attack Submarine (PEO SUB-X). Additionally, three intermediate point estimates were selected. These were one failure per year, (1.0), one failure in five years (0.2), and one failure in ten years (0.1). These values were chosen to provide other representative values for failure rates throughout the range discussed.

c. Unit Price

The unit price is simply the procurement price of the part before any surcharge is added. It is the price that the contractor was paid for the part. For the purposes of this model, five unit price values were used. These values represent the upper and lower bounds as well as three representative intermediate values. The upper bound was estimated to be $90,000.00. The lower bound was considered to be $1.00. The three

intermediate estimates were selected as $10.00, $1000.00, and $10,000.00. Based on the author's experience and discussions (Interview-AH, 1997), these values were thought to conservatively represent low cost, medium cost and high cost parts.

2. DLA Surcharge Rate

The DLA surcharge rate is the "tax" that DLA levies on each part issued to pay for managing the inventory of the part. It is a simple percentage of the unit price of the part. The DLA surcharge rate varies from fiscal year to fiscal year. The historical DLA surcharge rate for consumable items was unavailable (See Appendix B). The NAVICP surcharge rate history from Table 3.1 was used in predicting the DLA surcharge rate beyond FY-98. The predicted DLA surcharge rate was calculated by taking the average of the NAVICP consumable item surcharge rates for the period FY-91 through FY-98. This range of historical data was used because the shift was made to the working capital fund system (revolving fund) in FY-91. Prior to FY-91 the surcharge rates were lower because not all the costs of doing business in the supply management business area were being included in the surcharge. Previously, these "other" costs of doing business were covered by appropriated funds. The average of the values for the period FY-91 through FY-98 was used because the values resembled a uniform distribution across the range. The estimate for the DLA surcharge rate for FY-99 and beyond was calculated to be 36.1 percent.

3. Inflation

The inflation rate is the proportionate rate of change in the general price level per year, as opposed to the proportionate increase in a specific price. It is usually measured by a broad-based price index, such as the implicit deflator for Gross Domestic Product or the Consumer Price Index. (OMB, 1992) This variable can be changed when necessary. As mentioned earlier, an inflation rate of 2.7 percent is assumed for the life cycle of the New Attack Submarine per the guidance contained in *OMB Circular No. A-94* dated 29 October 1992, and the economic assumptions contained in the *Budget of the United States Government, Fiscal Year 1998* (OMB, 1992; OMB, 1997).

4. Discount Rate

The discount rate is the interest rate used in calculating the present value of the annual difference in costs. In accordance with the guidance of *OMB Circular No. A-94*, a discount rate of 6.3 percent was used in this model.

D. OTHER MODEL ASSUMPTIONS

1. The design of the model assumes that the price paid to the manufacturer of the part is the same whether the part is procured using intelligent digital data or whether it is issued from stock.

2. Thirty-three percent of the DLA surcharge is assumed to be a proxy for the holding costs associated with maintaining the part in inventory. The difference between the "cost from inventory" and the "cost from data" described above equates to the net present value of this holding cost. This is a conservative estimate of the annual savings/loss from using intelligent digital data. It also can be considered to be the value of the intelligent digital data for that part.

E. MODEL RESULTS

The model was used to conduct the analysis for the different values described in the previous section for the three part-specific variables while maintaining all other assumptions and treating all other variables as constants. The three variables, unit price, failure rate and population per platform, were each changed one at a time. Each variable was assigned five different values; a lower bound, representative low, medium and high intermediate values and an upper bound.

An output of the model is presented at the end of this appendix as Table C.6. The numbers shown in the table are from the analysis conducted using the high unit price ($10,000.00), high failure rate (one failure per year), and high population per platform (20) estimates. The values of the variable inputs are presented at the end of the output.

The model results using three variables with five values each resulted in 125 net present value figures. The 125 values presented in the five tables represent the various combinations of part specific variables. The net present value figures ranged from $1 for

the lower bound combination to $503 million for the upper bound combination. The range for the intermediate point estimates was from $70 to $7 million.

Unit Price =$90,000.00					
	Population per Platform				
Failure Rate	1	2	5	20	40
4	$12,583,957	$25,167,914	$62,919,786	$251,679,145	$503,358,291
1.0	$3,145,989	$6,291,978	$15,729,946	$62,919,786	$125,839,572
0.2	$629,197	$1,258,396	$3,145,989	$12,583,957	$25,167,914
0.1	$314,598	$629,197	$1,572,994	$6,291,978	$12,583,957
0.033	$103,817	$207,635	$519,088	$2,076,352	$4,152,705
Average Value			$45,634,965		

Table C.1. Model Results - Unit Price = $90,000.00.

Unit Price =$10,000.00					
	Population per Platform				
Failure Rate	1	2	5	20	40
4	$1,398,217	$2,796,434	$6,991,087	$27,964,349	$55,928,698
1.0	$349,554	$699,108	$1,747,771	$6,991,087	$13,982,174
0.2	$69,910	$139,821	$349,554	$1,398,217	$2,796,434
0.1	$34,955	$69,910	$174,777	$699,108	$1,398,217
0.033	$11,535	$23,070	$57,676	$230,705	$461,411
Average Value			$5,070,551		

Table C.2. Model Results - Unit Price = $10,000.00.

Unit Price =$1,000.00					
	Population per Platform				
Failure Rate	1	2	5	20	40
4	$139,821	$279,643	$699,108	$2,796,434	$5,592,869
1.0	$34,955	$69,910	$174,777	$699,108	$1,398,217
0.2	$6,991	$13,982	$34,955	$139,821	$279,643
0.1	$3,495	$6,991	$17,477	$69,910	$139,821
0.033	$1,153	$2,307	$5,767	$23,070	$46,141
Average Value			$507,054		

Table C.3. Model Results - Unit Price = $1,000.00

Unit Price =$10.00					
	Population per Platform				
Failure Rate	1	2	5	20	40
4	$1,398	$2,796	$6,991	$27,964	$55,928
1.0	$349	$699	$1,747	$6,991	$13,982
0.2	$70	$139	$349	$1,398	$2,796
0.1	$35	$70	$174	$699	$1,398
0.033	$11	$23	$57	$230	$461
Average Value			$5,070		

Table C.4. Model Results - Unit Price = $10.00

Unit Price =$1.00					
	Population per Platform				
Failure Rate	1	2	5	20	40
4	$139	$279	$699	$2,796	$5,592
1.0	$35	$70	$174	$699	$1,398
0.2	$7	$14	$35	$139	$279
0.1	$3	$7	$17	$70	$139
0.033	$1	$2	$6	$23	$46
Average Value			$507		

Table C.5. Model Results - Unit Price = $1.00

FISCAL YEAR	1998	1999	2000	2001	2002
YEAR	0	1	2	3	4
SUBS IN SERVICE	0	0	0	0	0
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	0.00	0.00	0.00	0.00	0.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	0.00	0.00	0.00	0.00	0.00
INFLATION FACTOR	1.00	1.03	1.05	1.08	1.11
UNIT PRICE	$10,000.00	$10,270.00	$10,547.29	$10,832.07	$11,124.53
SURCHARGE	$3,610.00	$3,707.47	$3,807.57	$3,910.38	$4,015.96
HOLDING COSTS	$1,202.13	$1,234.59	$1,267.92	$1,302.16	$1,337.31
COST FROM INVENTORY	$0.00	$0.00	$0.00	$0.00	$0.00
COST FROM DATA	$0.00	$0.00	$0.00	$0.00	$0.00
DIFFERENCE	$0.00	$0.00	$0.00	$0.00	$0.00
NET PRESENT VALUE	$6,991,087.37				

Table C.6. Net Present Value Model

FISCAL YEAR	2003	2004	2005	2006	2007
YEAR	5	6	7	8	9
SUBS IN SERVICE	0	1	2	2	3
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	0.00	20.00	40.00	40.00	60.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	0.00	20.00	40.00	40.00	60.00
INFLATION FACTOR	1.14	1.17	1.21	1.24	1.27
UNIT PRICE	$11,424.90	$11,733.37	$12,050.17	$12,375.52	$12,709.66
SURCHARGE	$4,124.39	$4,235.75	$4,350.11	$4,467.56	$4,588.19
HOLDING COSTS	$1,373.42	$1,410.50	$1,448.59	$1,487.70	$1,527.87
COST FROM INVENTORY	$0.00	$319,382.25	$656,011.15	$673,723.45	$1,037,870.98
COST FROM DATA	$0.00	$291,172.19	$598,067.68	$614,215.50	$946,198.98
DIFFERENCE	$0.00	$28,210.07	$57,943.47	$59,507.95	$91,671.99

Table C.6. Net Present Value Model

FISCAL YEAR	2008	2009	2010	2011	2012
YEAR	10	11	12	13	14
SUBS IN SERVICE	4	5	6	7	8
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	80.00	100.00	120.00	140.00	160.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	80.00	100.00	120.00	140.00	160.00
INFLATION FACTOR	1.31	1.34	1.38	1.41	1.45
UNIT PRICE	$13,052.82	$13,405.25	$13,767.19	$14,138.90	$14,520.66
SURCHARGE	$4,712.07	$4,839.29	$4,969.96	$5,104.14	$5,241.96
HOLDING COSTS	$1,569.12	$1,611.49	$1,655.00	$1,699.68	$1,745.57
COST FROM INVENTORY	$1,421,191.33	$1,824,454.36	$2,248,457.56	$2,694,026.90	$3,162,017.86
COST FROM DATA	$1,295,661.81	$1,663,305.85	$2,049,858.13	$2,456,071.68	$2,882,726.41
DIFFERENCE	$125,529.52	$161,148.52	$198,599.43	$237,955.22	$279,291.44

Table C.6. Net Present Value Model

FISCAL YEAR	2013	2014	2015	2016	2017
YEAR	15	16	17	18	19
SUBS IN SERVICE	10	11	13	14	16
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	200.00	220.00	260.00	280.00	320.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	200.00	220.00	260.00	280.00	320.00
INFLATION FACTOR	1.49	1.53	1.57	1.62	1.66
UNIT PRICE	$14,912.71	$15,315.36	$15,728.87	$16,153.55	$16,589.70
SURCHARGE	$5,383.49	$5,528.84	$5,678.12	$5,831.43	$5,988.88
HOLDING COSTS	$1,792.70	$1,841.10	$1,890.81	$1,941.87	$1,994.30
COST FROM INVENTORY	$4,059,240.42	$4,585,723.91	$5,565,818.17	$6,155,794.90	$7,225,144.41
COST FROM DATA	$3,700,700.04	$4,180,680.83	$5,074,206.34	$5,612,072.21	$6,586,969.33
DIFFERENCE	$358,540.39	$405,043.08	$491,611.83	$543,722.68	$638,175.08

Table C.6. Net Present Value Model

FISCAL YEAR	2018	2019	2020	2021	2022
YEAR	20	21	22	23	24
SUBS IN SERVICE	17	19	20	22	23
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	340.00	380.00	400.00	440.00	460.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	340.00	380.00	400.00	440.00	460.00
INFLATION FACTOR	1.70	1.75	1.80	1.85	1.90
UNIT PRICE	$17,037.62	$17,497.63	$17,970.07	$18,455.26	$18,953.55
SURCHARGE	$6,150.58	$6,316.65	$6,487.20	$6,662.35	$6,842.23
HOLDING COSTS	$2,048.14	$2,103.44	$2,160.24	$2,218.56	$2,278.46
COST FROM INVENTORY	$7,883,987.27	$9,049,426.09	$9,782,905.89	$11,051,748.78	$11,866,061.73
COST FROM DATA	$7,187,618.60	$8,250,117.74	$8,918,811.50	$10,075,581.35	$10,817,968.50
DIFFERENCE	$696,368.67	$799,308.35	$864,094.39	$976,167.43	$1,048,093.22

Table C.6. Net Present Value Model

FISCAL YEAR	2023	2024	2025	2026	2027
YEAR	25	26	27	28	29
SUBS IN SERVICE	25	26	28	29	30
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	500.00	520.00	560.00	580.00	600.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	500.00	520.00	560.00	580.00	600.00
INFLATION FACTOR	1.95	2.00	2.05	2.11	2.17
UNIT PRICE	$19,465.30	$19,990.86	$20,530.62	$21,084.94	$21,654.24
SURCHARGE	$7,026.97	$7,216.70	$7,411.55	$7,611.66	$7,817.18
HOLDING COSTS	$2,339.98	$2,403.16	$2,468.05	$2,534.68	$2,603.12
COST FROM INVENTORY	$13,246,136.30	$14,147,933.26	$15,647,614.18	$16,644,031.90	$17,682,849.06
COST FROM DATA	$12,076,145.27	$12,898,289.25	$14,265,507.90	$15,173,915.07	$16,120,976.66
DIFFERENCE	$1,169,991.02	$1,249,644.01	$1,382,106.28	$1,470,116.83	$1,561,872.40

Table C.6. Net Present Value Model

FISCAL YEAR	2028	2029	2030	2031	2032
YEAR	30	31	32	33	34
SUBS IN SERVICE	30	30	30	30	30
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	600.00	600.00	600.00	600.00	600.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	600.00	600.00	600.00	600.00	600.00
INFLATION FACTOR	2.22	2.28	2.35	2.41	2.47
UNIT PRICE	$22,238.90	$22,839.35	$23,456.01	$24,089.33	$24,739.74
SURCHARGE	$8,028.24	$8,245.01	$8,467.62	$8,696.25	$8,931.05
HOLDING COSTS	$2,673.40	$2,745.59	$2,819.72	$2,895.85	$2,974.04
COST FROM INVENTORY	$18,160,285.99	$18,650,613.71	$19,154,180.28	$19,671,343.15	$20,202,469.41
COST FROM DATA	$16,556,243.03	$17,003,261.60	$17,462,349.66	$17,933,833.10	$18,418,046.59
DIFFERENCE	$1,604,042.95	$1,647,352.11	$1,691,830.62	$1,737,510.05	$1,784,422.82

Table C.6. Net Present Value Model

FISCAL YEAR	2033	2034	2035	2036	2037
YEAR	35	36	37	38	39
SUBS IN SERVICE	30	30	29	28	28
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	600.00	600.00	580.00	560.00	560.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	600.00	600.00	580.00	560.00	560.00
INFLATION FACTOR	2.54	2.61	2.68	2.75	2.83
UNIT PRICE	$25,407.71	$26,093.72	$26,798.25	$27,521.80	$28,264.89
SURCHARGE	$9,172.18	$9,419.83	$9,674.17	$9,935.37	$10,203.63
HOLDING COSTS	$3,054.34	$3,136.80	$3,221.50	$3,308.48	$3,397.81
COST FROM INVENTORY	$20,747,936.09	$21,308,130.36	$21,154,001.55	$20,976,016.16	$21,542,368.60
COST FROM DATA	$18,915,333.85	$19,426,047.87	$19,285,532.79	$19,123,268.30	$19,639,596.55
DIFFERENCE	$1,832,602.23	$1,882,082.49	$1,868,468.76	$1,852,747.85	$1,902,772.05

Table C.6. Net Present Value Model

FISCAL YEAR	2038	2039	2040	2041	2042
YEAR	40	41	42	43	44
SUBS IN SERVICE	27	26	24	23	22
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	540.00	520.00	480.00	460.00	440.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	540.00	520.00	480.00	460.00	440.00
INFLATION FACTOR	2.90	2.98	3.06	3.14	3.23
UNIT PRICE	$29,028.04	$29,811.80	$30,616.72	$31,443.37	$32,292.34
SURCHARGE	$10,479.12	$10,762.06	$11,052.64	$11,351.06	$11,657.53
HOLDING COSTS	$3,489.55	$3,583.77	$3,680.53	$3,779.90	$3,881.96
COST FROM INVENTORY	$21,333,869.24	$21,098,406.54	$20,001,289.40	$19,685,435.70	$19,337,944.97
COST FROM DATA	$19,449,513.31	$19,234,848.31	$18,234,636.20	$17,946,680.90	$17,629,882.97
DIFFERENCE	$1,884,355.93	$1,863,558.23	$1,766,653.20	$1,738,754.80	$1,708,062.00

Table C.6. Net Present Value Model

FISCAL YEAR	2043	2044	2045	2046	2047
YEAR	45	46	47	48	49
SUBS IN SERVICE	20	19	17	16	14
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	400.00	380.00	340.00	320.00	280.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	400.00	380.00	340.00	320.00	280.00
INFLATION FACTOR	3.32	3.41	3.50	3.59	3.69
UNIT PRICE	$33,164.23	$34,059.67	$34,979.28	$35,923.72	$36,893.66
SURCHARGE	$11,972.29	$12,295.54	$12,627.52	$12,968.46	$13,318.61
HOLDING COSTS	$3,986.77	$4,094.41	$4,204.96	$4,318.50	$4,435.10
COST FROM INVENTORY	$18,054,608.62	$17,614,978.90	$16,186,311.40	$15,645,498.17	$14,059,435.80
COST FROM DATA	$16,459,899.83	$16,059,101.27	$14,756,623.63	$14,263,578.80	$12,817,608.50
DIFFERENCE	$1,594,708.79	$1,555,877.63	$1,429,687.77	$1,381,919.38	$1,241,827.30

Table C.6. Net Present Value Model

FISCAL YEAR	2048	2049	2050	2051	2052
YEAR	50	51	52	53	54
SUBS IN SERVICE	13	11	10	8	7
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	260.00	220.00	200.00	160.00	140.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	260.00	220.00	200.00	160.00	140.00
INFLATION FACTOR	3.79	3.89	4.00	4.10	4.22
UNIT PRICE	$37,889.79	$38,912.81	$39,963.46	$41,042.47	$42,150.62
SURCHARGE	$13,678.21	$14,047.53	$14,426.81	$14,816.33	$15,216.37
HOLDING COSTS	$4,554.85	$4,677.83	$4,804.13	$4,933.84	$5,067.05
COST FROM INVENTORY	$13,407,680.52	$11,651,274.37	$10,878,053.44	$8,937,408.70	$8,031,378.90
COST FROM DATA	$12,223,420.79	$10,622,152.66	$9,917,227.99	$8,147,994.51	$7,321,991.57
DIFFERENCE	$1,184,259.73	$1,029,121.71	$960,825.45	$789,414.19	$709,387.33

Table C.6. Net Present Value Model

FISCAL YEAR	2053	2054	2055	2056	2057
YEAR	55	56	57	58	59
SUBS IN SERVICE	5	4	2	1	0
POPULATION PER PLATFORM	20.00	20.00	20.00	20.00	20.00
TOTAL POPULATION	100.00	80.00	40.00	20.00	0.00
FAILURE RATE	1.00	1.00	1.00	1.00	1.00
DEMAND	100.00	80.00	40.00	20.00	0.00
INFLATION FACTOR	4.33	4.45	4.57	4.69	4.82
UNIT PRICE	$43,288.69	$44,457.48	$45,657.83	$46,890.59	$48,156.64
SURCHARGE	$15,627.22	$16,049.15	$16,482.48	$16,927.50	$17,384.55
HOLDING COSTS	$5,203.86	$5,344.37	$5,488.66	$5,636.86	$5,789.05
COST FROM INVENTORY	$5,891,590.09	$4,840,530.42	$2,485,612.37	$1,276,361.95	$0.00
COST FROM DATA	$5,371,203.82	$4,412,981.06	$2,266,065.77	$1,163,624.77	$0.00
DIFFERENCE	$520,386.27	$427,549.36	$219,546.60	$112,737.18	$0.00

Table C.6. Net Present Value Model

PART SPECIFIC VARIABLES	
POPULATION PER PLATFORM	20.00
FAILURE RATE	1.00
UNIT PRICE	$10,000.00

EXTERNAL VARIABLES	
DLA SURCHARGE	0.361
INFLATION	0.027
DISCOUNT RATE	0.063

Table C.6. Net Present Value Model

TOTAL POPULATION = (SUBS IN SERVICE) X (POPULATION PER PLATFORM)

DEMAND = (FAILURE RATE) X (TOTAL POPULATION)

INFLATION FACTOR = (1+i)^n

HOLDING COSTS = (SURCHARGE) X (0.333)

COST FROM INVENTORY = (DEMAND) X (UNIT PRICE + SURCHARGE)

COST FROM DATA = (DEMAND) X ((UNIT PRICE) + (SURCHARGE - HOLDING COST))

DIFFERENCE = (COST FROM INVENTORY) - (COST FROM DATA)

NET PRESENT VALUE = NPV OF DIFFERENCE

Table C.6. Net Present Value Model

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APPENDIX D. REVERSE ENGINEERING COST ESTIMATION

Another approach to estimating the value of intelligent digital data is to ask the question "What would it cost to do it ourselves?". The cost of producing the intelligent digital data equates to the cost of reverse engineering the parts using RAMP technology. Simply, the Navy should not pay any more for the intelligent digital data for a part than it would cost the Navy to generate that data from a reverse engineering process.

The costs of reverse engineering using RAMP technology vary according to whether the part is a small mechanical part (SMP) or a printed wire assembly (PWA), the amount of technical documentation available, and the complexity of the part. For PWAs the complexity involves the number of layers and discrete components associated with the PWA. For SMPs the complexity involves the number of features, (i.e., surfaces, finishes, and penetrations). To estimate the cost of reverse engineering, a complexity rating would need to be identified along with an available documentation factor. A documentation factor addresses the amount of documentation available to describe the part. These two factors could be combined to generate a time estimate to accomplish the reverse engineering. This time estimate could then be multiplied times the cost per hour of the reverse engineering process to obtain an estimated cost for the reverse engineering process.

A proposed cost estimate model is provided below using hypothetical numbers, due to the lack of actual numbers and relationships.

A. COMPLEXITY RATING

The basis for the complexity rating varies between PWAs and SMPs. For PWAs complexity depends on the number of layers and discrete components attached to the PWA. For SMPs complexity depends on the number of features. A hypothetical complexity rating matrix is provided as Table D.1 (Interview-N, 1997; Interview-T, 1997: Interview-AI, 1997))[5]. The matrix is entered with the number the complexity factor characteristics of the part (i.e., For an SMP, the number of features). For a PWA, the number of layers and discrete components.) The matrix will then provide a complexity rating with which to enter Table D.3 or D.4.

Complexity Rating						
	1		2		3	
	SMP	PWA	SMP	PWA	SMP	PWA
Features	0-10	--	10-20	--	20-50	--
Layers	--	0-2	--	2-4	--	4-8
Discrete Components	--	0-50	--	50-150	--	150-250

Table D.1. Complexity Factors.

[5] The numbers used in this matrix and subsequent matrices in this appendix are hypothetical. They are based on discussions and a single average point estimate.

B. DOCUMENTATION FACTOR

The basis for the documentation factor is simply how much supporting documentation is available to assist in the reverse engineering process. Documentation is any information that describes the function or composition of the part. It can take the form of design drawings, technical manuals, or maintenance procedures. A hypothetical documentation factor table is provided as Table D.2.

Documentation Factors	
1	Sample data providing physical description.
2	Some data, providing physical and functional description including tolerances, finishes, interfaces, design intent, and environmental intent.
3	Available data provides physical, functional, and manufacturing process description. Also provides test process information.

Table D.2. Documentation Factors (Interview-AI, 1997)

C. REVERSE ENGINEERING TIME ESTIMATION

The time estimation process for reverse engineering takes the form of determining a value from a matrix based on both the complexity and documentation factors developed from Tables D.1 and D.2 above. Hypothetical time estimation matrices are provided as Table D.3 and D.4. These tables are loosely based on interview data (Interview-T, 1997; Interview-H, 1997; Interview-AI, 1997). Table D.3 is for estimating time for SMPs. Table D.4 is for estimating time for PWAs.

Reverse Engineering Time Estimation Table (Hours) - SMP			
	Documentation Factor		
Complexity Rating	1	2	3
1	4	3	2
2	6	5	4
3	12	10	8

Table D.3. Reverse Engineering Time Estimation Table - SMP

Reverse Engineering Time Estimation Table (Hours) - PWA			
	Documentation Factor		
Complexity Factor	1	2	3
1	90	82	66
2	120	90	84
3	140	115	105

Table D.4. Reverse Engineering Time Estimation Table - PWA

D. REVERSE ENGINEERING COST CALCULATION

The reverse engineering cost calculation is simply the product of multiplying the time estimate in hours by the cost per hour. Using the time estimates from the time estimation matrices (Tables D.3 and D.4) and assuming the cost per hour to be $75.00 per hour, examples of cost calculations for both a PWA and an SMP are provided in Table D.5.

Reverse Engineering Cost Calculation					
Part	Complexity Rating (Table D.1)	Documentation Rating (Table D.2)	Time Estimate (hours) (Table D.3)	Cost per Hour	Reverse Engineering Cost
PWA (Example)	2	1	120	$75.00	$9,000.00
SMP (Example)	3	2	10	$75.00	$750.00

Table D.5. Reverse Engineering Cost Calculation Example

E. SUMMARY

This method of cost estimation could be very useful not only in estimating the cost of intelligent data for the purposes of procuring the data, but also for the purposes of evaluating whether it would be cost effective to reverse engineer an existing part for the purposes of exploring alternative sources of procurement. The example numbers provided in the explanation of this method were for the most part hypothetical. However, at least one number used was realistic, and was obtained during interviews with various RAMP facility managers. The cost per hour to reverse engineer is approximately $75.00. It is generally more time consuming to reverse engineer a PWA than it is a SMP. Other than that, no conclusions should be drawn based on the numbers in these examples.

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LIST OF REFERENCES

Acquisition Reform Office. *NSSN Embraces Acquisition Reform*. Acquisition Reform Update Newsletter. Vol. 3. No. 1. January 1996.

Ahern, Michael G. Allocating the Increased Operational Costs in Retail Prices at the Defense Electronics Supply Center as a Result of Defense Management Report Decision 901. Master's Thesis. Naval Postgraduate School. Monterey, CA. June 1991.

Burton, Chester. The Navy's RAMP Program (A). Case Study UVA-C-2073. Darden Graduate School of Business Administration, University of Virginia. Charlottesville, VA. 1990.

Chief of Naval Operations, Code 802K. *Historical Force Levels FY-62 Through FY-93.* Ship Forces of the U.S. Navy. Working Papers. May 1994.

Cohen, William S., Secretary of Defense. *Report of the Quadrennial Defense Review.* May 1997.

Continuous Acquisition and Lifecycle Support (CALS). Website. http:\\www.cals.osd.mil. October 1996.

Continuous Acquisition and Lifecycle Support (CALS). Website. http:\\www.cals.osd.mil. April 1997.

Dalton, John H., Secretary of the Navy. *FY 1998/FY 1999 Department of the Navy Budget Submission to the Secretary of Defense*. 16 September 1996.

Defense Logistics Agency (DLA). Annual Report. 1996

Defense Systems Management College (DSMC). *A-12 Report Exercise Student Guide*. 1996.

Department of Defense Directive 1000B. *Military Specification Drawings, Engineering and Associated Lists*. 28 October 1977 with Amendment 3 dated 13 May 1985.

Department of Defense Regulation 5000.2R. *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*. March 15, 1996.

Electronic Commerce Information Center (ECIC). Your Introduction to Electronic Commerce. Electronic Commerce Office, Office of the Deputy Under Secretary of Defense (Acquisition Reform). 1995.

Emahiser, James B., Assistant Secretary of Defense for Materiel and Distribution Management. *Prepared Remarks to the National Security, International Affairs and Criminal Justice Subcommittee, House Government Reform and Oversight Committee*. March 20, 1997.

Evers, Stacey. "Obsolete Parts Plague F-22 Before First Flight." *Jane's Defence Weekly*. 13 August 1997.

Hamre, John J. Under Secretary of Defense. Memorandum on: *Management Reform Memorandum #2 -- Moving to a Paper-free Contracting Process by January 1, 2000*. 21 May 1997.

IBM. *CATIA-CADAM Solutions*. IBM/Dassault Systemes Website. http://www.catia.ibm.com. June 1997.

Institute for Defense Analysis. *The Future of Military R&D: Towards a Flexible Acquisition Strategy*. Alexandria, VA. Defense Technical Information Center. 1990.

Interview-A. Interviews between NAVSEA Submarine Program Design Management Branch Head and the author, between 1 July and 1 August 1997.

Interview-B. Interviews between NAVSEA Submarine Program Logistics Branch Head and the author, between 21 October 1996 and 1 August 1997.

Interview-C. Interview between NAVSEA Contracting Officer and the author, 2 July 1997.

Interview-D. Interview between NAVSEA Environmental and Support Systems Equipment Branch, Project Manager, and the author, 2 July 1997.

Interview-E. Interview between NAVICP Deputy Code 84 and the author, 5 March 1997.

Interview-F. Interview between NAVSEA New Attack Submarine Program Manager and the author, 11 October 1996.

Interview-G. Interview between NAVSUP RAMP Program Manager and the author, 5 December 1996.

Interview-N. Interview between NAVSUP RAMP Program Supervisor at SCRA and the author, 21 March 1997.

Interview-O. Interview between NAVSEA Code 92LA and the author, 21 March 1997.

Interview-P. Interview between NAVSEA Code 92LA and the author, 16 April 1997.

Interview-S. Interview between NAVSEA Code 350A and the author, 1 July 1997.

Interview-T. Interview between NAWC Indianapolis, RAMP Cell and the author, 4 August 1997.

Interview-U. Interview between RAMP Program STEP Subject Matter Expert and the author, 4 August 1997.

Interview-V. Interview between NAVSEA Code 350A11 and the author, 2 July 1997.

Interview-X. Interview between Anniston Army Depot RAMP Manufacturing Facility Manager and the author, 1 August 1997.

Interview-Z. Interview between NAVICP RAMP Liaison and the author, 18 August 1997.

Interview-AA. Interview between NAVICP Comptroller staff and the author, 29 August 1997.

Interview-AC. Interview between NAVICP Code 84 and the author, 29 August 1997.

Interview-AH. Interview between Defense Logistics Agency Supply Operations Team Chief and the author 15 September 1997.

Interview-AI. Interview between SCRA Program Manager and the author, 16 September 1997.

Interview-AJ. Interview between DLA Business Management Team Leader and the author, 17 September 1997.

Jones, Anita K., Director of Defense Research and Engineering. *Statement to the Subcommittee on Military Research and Development of the House National Security Committee*. February, 27 1997.

Kowenhaven, William H., and Harris, Frederick J. *The NSSN A 21st Century Design*. U. S. Naval Institute Proceedings. U. S. Naval Institute Press. June 1997.

McGraw-Hill Incorporated. *Manufacturing System Integration*. McGraw-Hill Yearbook of Science and Technology 1995. McGraw-Hill Incorporated. 1995.

McGraw-Hill Incorporated. *Printed Circuits*. McGraw-Hill Encyclopedia of Science and Technology. Sixth Edition. McGraw-Hill Incorporated. 1987.

Mendenhall, William. Introduction to Probability and Statistics. PWS-Kent Publishing Company. Boston. 7th Edition. 1987.

Moore, John. Janes Fighting Ships 1983-84. Janes Publishing Company LTD. London. 1983.

Moore, John. Janes Fighting Ships 1997-98. Janes Publishing Company LTD. London. 1997.

National Academy of Engineering. *The Changing Demands on National Technology Policy and Strategy*. In Mastering a New Role. Washington, D. C.: National Academy Press. 1993.

Naval Postgraduate School. Department of Systems Management. *Course Reader for Financial Management in the Armed Forces, MN 3143*. October 1996.

Naval Sea Systems Command (NAVSEA). Reelable Towed Array Handling System Type OK-276A/BQ, OK-276()/BQ and OK-418/BQ. NAVSEA SE325-CB-MMA-010. Revision 1 dated 28 February 1993 with Change B dated 31 May 1997.

Naval Supply Systems Command (NAVSUP). Inventory Management. NAVSUP Publication 553. 1991.

Office of Management and Budget. *Budget of the United States Government for Fiscal Year 1998*. 1997.

Perry, William J., Secretary of Defense. *Testimony before the Senate Armed Services Committee*. 1996.

Perry, William J., Secretary of Defense. *Annual Report to the President and the Congress*. 1997.

Peterson, Marlene J., A Management Case Study: The implementation of the Rapid Acquisition of Manufactured Parts (RAMP) Program, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1993.

Phillips, John F. Deputy Under Secretary of Defense (Logistics). Memorandum on: *Life-Cycle Information Integration*. 17 July 1997.

Philpott, Tom. *Congressional Update: Submarines.* U. S. Naval Institute Proceedings. Vol. 123, No.5. May 1997.

Polmar, Norman. *The U. S. Navy: A New Direction for Submarines*. United States Naval Institute Proceedings. March 1996.

Longuemare, R. Noel. Principal Deputy Under Secretary of Defense. Memorandum on: *Acquisition of Information in Digital Format*. 4 June 1996.

Program Executive Officer Submarines, PEO Sub-X. Integrated Logistics Support Plan for Fleet Introduction of the New Attack Submarine (NSSN). September 1993.

South Carolina Research Authority (SCRA). *RAMP* Website. http:// ramp.scra.org. October 1996.

South Carolina Research Authority (SCRA). SCRA Website. http:\\www.scra.org. May 1997.

St. Charles, David P. *Solving the Factory Automation Paradox*. Computer-Aided Engineering. July 1989.

United States General Accounting Office Report. NAVY SHIPS: Seawolf Cost Increases and Schedule Delays Continue. GAO/NSIAD-94-201BR. 30 June 1994.

United States General Accounting Office Report. DEFENSE INVENTORY: Changes in DOD's Inventory, 1989-93. GAO/NSIAD-94-235. 17 August 1994.

United States General Accounting Office Report. DEFENSE SUPPLY: Acquisition Lead time Requirements Can Be Significantly Reduced. GAO/NSIAD-95-2. 20 December 1994.

United States General Accounting Office Report. DEFENSE INVENTORY: Extent of Diminishing Manufacturing Sources Problems Still Unknown. GAO/NSIAD-95-85. 21 April 1995.

United States General Accounting Office Report. INVENTORY MANAGEMENT: DOD Can Build on Progress in Using Best Practices to Achieve Substantial Savings. GAO/NSIAD-95-142. 4 August 1995.

United States General Accounting Office Report. INVENTORY MANAGEMENT: Adopting Best Practices Could Enhance Navy Effects to Achieve Efficiencies and Savings. GAO/NSIAD-96-156. 12 July 1996.

United States General Accounting Office Report. New Attack Submarine Program Status. GAO/NSIAD-97-25. 3 December 1996.

United States General Accounting Office Report. DEFENSE INVENTORY: Spare and Repair Parts Inventory Costs Can Be Reduced. GAO/NSIAD-97-47. January 1997.

Walls. Gregory. "Program Budget and Execution." *Principles of Program Management II (MN 3222) Course Curriculum*. Naval Postgraduate School. Monterey, CA. May 1997.

Webster's II New Riverside University Dictionary. Riverside Publishing Company. Boston. 1984.

BIBLIOGRAPHY

Acquisition Reform Office. *NSSN Embraces Acquisition Reform*. Acquisition Reform Update Newsletter. Vol. 3. No. 1. January 1996.

Ahern, Michael G. Allocating the Increased Operational Costs in Retail Prices at the Defense Electronics Supply Center as a Result of Defense Management Report Decision 901. Master's Thesis. Naval Postgraduate School. Monterey, CA. June 1991.

Bryant, Michael B. A Study of the Adequacy of the Navy Industrial Fund Accounting System for use with the RAMP SMP Facility, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1988.

Burton, Chester. The Navy's RAMP Program (A). Case Study UVA-C-2073. Darden Graduate School of Business Administration, University of Virginia. Charlottesville, VA. 1990.

Chief of Naval Operations, Code 802K. *Historical Force Levels FY-62 Through FY-93*. Ship Forces of the U.S. Navy. Working Papers. May 1994.

Choobineh, Fred, and Suri, Rajan. Flexible Manufacturing Systems, Current Issues and Models. Industrial Engineering and Management Press. Atlanta. 1986.

Cohen, William S., Secretary of Defense. *Report of the Quadrennial Defense Review*. May 1997.

Continuous Acquisition and Lifecycle Support (CALS). Website. http:\\www.cals.osd.mil. October 1996.

Continuous Acquisition and Lifecycle Support (CALS). Website. http:\\www.cals.osd.mil. April 1997.

Dalton, John H., Secretary of the Navy. *FY 1998/FY 1999 Department of the Navy Budget Submission to the Secretary of Defense*. 16 September 1996.

Deakin, Edward B., and Maher, Michael W., Cost Accounting, Fourth Edition, Irwin, 1994.

Defense Logistics Agency (DLA). Annual Report. 1996

Defense Systems Management College (DSMC). *A-12 Report Exercise Student Guide*. 1996.

Department of Defense Directive 1000B. *Military Specification Drawings, Engineering and Associated Lists*. 28 October 1977 with Amendment 3 dated 13 May 1985.

Department of Defense Directive 5000.1. *Defense Acquisition*. March 15, 1996.

Department of Defense Regulation 5000.2R. *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*. March 15, 1996.

Electronic Commerce Information Center (ECIC). Your Introduction to Electronic Commerce. Electronic Commerce Office, Office of the Deputy Under Secretary of Defense (Acquisition Reform). 1995.

Emahiser, James B., Assistant Secretary of Defense for Materiel and Distribution Management. *Prepared Remarks to the National Security, International Affairs and Criminal Justice Subcommittee, House Government Reform and Oversight Committee*. March 20, 1997.

Evers, Stacey. "Obsolete Parts Plague F-22 Before First Flight." *Jane's Defence Weekly*. 13 August 1997.

Hamre, John J. Under Secretary of Defense. Memorandum on: *Management Reform Memorandum #2 -- Moving to a Paper-free Contracting Process by January 1, 2000*. 21 May 1997.

Holzer, Robert. *Team Plan for NSSN May Erase Long-Term Cost Cuts*. The Worldwide Weekly Defense News, Vol. 12, No. 2, (January 13-19 1997).

IBM. *CATIA-CADAM Solutions*. IBM/Dassault Systemes Website. http:// www.catia.ibm.com. June 1997.

Institute for Defense Analysis. *The Future of Military R&D: Towards a Flexible Acquisition Strategy*. Alexandria, VA. Defense Technical Information Center. 1990.

Interview-A. Interviews between NAVSEA Submarine Program Design Management Branch Head and the author, between 1 July and 1 August 1997.

Interview-B. Interviews between NAVSEA Submarine Program Logistics Branch Head and the author, between 21 October 1996 and 1 August 1997.

Interview-C. Interview between NAVSEA Contracting Officer and the author, 2 July 1997.

Interview-D. Interview between NAVSEA Environmental and Support Systems Equipment Branch, Project Manager, and the author, 2 July 1997.

Interview-E. Interview between NAVICP Deputy Code 84 and the author, 5 March 1997.

Interview-F. Interview between NAVSEA New Attack Submarine Program Manager and the author, 11 October 1996.

Interview-G. Interview between NAVSUP RAMP Program Manager and the author, 5 December 1996.

Interview-H. Interviews between NAVSUP RAMP Program Project Supervisor and the author, between 5 December 1996 and 18 August 1997.

Interview-I. Interview between NAVICP Item Manager and the author, 7 March 1997.

Interview-J. Interview between NAVICP Item Manager and the author, 10 March 1997.

Interview-K. Interview between NAVICP Item Manager and the author, 10 March 1997.

Interview-L. Interview between NAVICP Data System Supervisor and the author, 10 March 1997.

Interview-M. Interview between NAVICP Planning and Data Systems Manager, and the author, 21 March 1997.

Interview-N. Interviews between NAVSUP RAMP Program Supervisor at SCRA and the author, between 21 March 1997 and 15 August 1997.

Interview-O. Interview between NAVSEA Code 92LA and the author, 21 March 1997.

Interview-P. Interview between NAVSEA Code 92LA and the author, 16 April 1997.

Interview-Q. Interview between FMSO Submarine Support Manager and the author, 21 April 1997.

Interview-R. Interview between NAVSEA Code 92LA1 and the author, 21 April 1997.

Interview-S. Interview between NAVSEA Code 350A and the author, 1 July 1997.

Interview-T. Interview between NAWC Indianapolis, RAMP Cell and the author, 4 August 1997.

Interview-U. Interview between RAMP Program STEP Subject Matter Expert and the author, 4 August 1997.

Interview-V. Interview between NAVSEA Code 350A11 and the author, 2 July 1997.

Interview-W. Interview between Anniston Army Depot RAMP Facility Manager and the author, 15 August 1997.

Interview-X. Interview between Anniston Army Depot RAMP Manufacturing Facility Manager and the author, 1 August 1997.

Interview-Y. Interview between NAVICP Code 021 and the author, 29 August 1997.

Interview-Z. Interview between NAVICP RAMP Liaison and the author, 18 August 1997.

Interview-AA. Interview between NAVICP Comptroller staff and the author, 29 August 1997.

Interview-AB. Interview between NAVICP Code 8414 and the author, 29 August 1997.

Interview-AC. Interview between NAVICP Code 84 and the author, 29 August 1997.

Interview-AD. Interview between NAVSUP RAMP Program Deputy Program Manager and the author, 9 October 1996.

Interview-AE. Interview between NAVSEA Code 350A222 and the author, 2 July 1997.

Interview-AF. Interview between NAVSEA Code 350 Financial Management and the author, 2 July 1997.

Interview-AG. Interview between NAVSEA Code 350AB and the author, 1 July 1997.

Interview-AH. Interview between Defense Logistics Agency Supply Operations Team Chief and the author 15 September 1997.

Interview-AI. Interview between SCRA Program Manager and the author, 16 September 1997.

Interview-AJ. Interview between DLA Business Management Team Leader and the author, 17 September 1997.

Jones, Anita K., Director of Defense Research and Engineering. *Statement to the Subcommittee on Military Research and Development of the House National Security Committee*. February, 27 1997.

Kaminski, Paul. *Affordability in the Submarine Force*. Presentation to the Submarine Technology Symposium 1996, at the Johns Hopkins Applied Physics Laboratory, Laurel, MD. 16 May 1996.

Kowenhaven, William H., and Harris, Frederick J. *The NSSN A 21st Century Design*. U. S. Naval Institute Proceedings. U. S. Naval Institute Press. June 1997.

Martin, Michael P., Performance Measurement in the RAMP SMP Facility, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1989.

McGraw-Hill Incorporated. *Manufacturing System Integration*. McGraw-Hill Yearbook of Science and Technology 1995. McGraw-Hill Incorporated. 1995

McGraw-Hill Incorporated. *Printed Circuits*. McGraw-Hill Encyclopedia of Science and Technology. Sixth Edition. McGraw-Hill Incorporated. 1987.

Mendenhall, William. Introduction to Probability and Statistics. PWS-Kent Publishing Company. Boston. 7th Edition. 1987.

Moore, John. Janes Fighting Ships 1983-84. Janes Publishing Company LTD. London. 1983.

Moore, John. Janes Fighting Ships 1997-98. Janes Publishing Company LTD. London. 1997.

National Academy of Engineering. *The Changing Demands on National Technology Policy and Strategy*. In Mastering a New Role. Washington, D. C.: National Academy Press. 1993.

Naval Postgraduate School. Department of Systems Management. *Course Reader for Financial Management in the Armed Forces, MN 3143*. October 1996.

Naval Sea Systems Command (NAVSEA). Reelable Towed Array Handling System Type OK-276A/BQ, OK-276()/BQ and OK-418/BQ. NAVSEA SE325-CB-MMA-010. Revision 1 dated 28 February 1993 with Change B dated 31 May 1997.

Naval Supply Systems Command (NAVSUP). Inventory Management. NAVSUP Publication 553. 1991.

Office of Management and Budget. *Budget of the United States Government for Fiscal Year 1998*. 1997.

Perry, William J., Secretary of Defense. *Testimoney before the Senate Armed Services Committee*. 1996.

Perry, William J., Secretary of Defense. *Annual Report to the President and the Congress*. 1997.

Peterson, Marlene J., A Management Case Study: The implementation of the Rapid Acquisition of Manufactured Parts (RAMP) Program, Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1993.

Phillips, John F. Deputy Under Secretary of Defense (Logistics). Memorandum on: *Life-Cycle Information Integration*. 17 July 1997.

Philpott, Tom. *Congressional Update: Submarines.* U. S. Naval Institute Proceedings. Vol. 123, No.5. May 1997.

Polmar, Norman. *The U. S. Navy: A New Direction for Submarines*. United States Naval Institute Proceedings. March 1996.

Longuemare, R. Noel. Principal Deputy Under Secretary of Defense. Memorandum on: *Acquisition of Information in Digital Format*. 4 June 1996.

Program Executive Officer Submarines, PEO Sub-X. Integrated Logistics Support Plan for Fleet Introduction of the New Attack Submarine (NSSN). September 1993.

Robinson, John. *Pentagon, Navy Hammer Out Submarine Deal for NNS, EB*. Defense Daily as reprinted in The Early Bird. 10 January 1997.

Scheer, August Wilhelm. CIM: Towards the Factory of the Future. 2nd Edition. Springer-Verlag. New York. 1991.

South Carolina Research Authority (SCRA). *RAMP* Website. http:\\ramp.scra.org. October 1996.

South Carolina Research Authority (SCRA). SCRA Website. http:\\www.scra.org. May 1997.

St. Charles, David P. *Solving the Factory Automation Paradox*. Computer-Aided Engineering. July 1989.

United States General Accounting Office Report. Navy Ships: Status of SSN-21 Ship Construction Program. GAO/NSIAD-90-163. 19 April 1990.

United States General Accounting Office Report. Navy Ships: Problems Continue to Plague the SEAWOLF Submarine Program. GAO/NSIAD-92-171. 3 December 1996.

United States General Accounting Office Report. Navy Ships: Status of SSN-21 Design and Lead Ship Construction Program. GAO/NSIAD-93-34. 17 November 1992.

United States General Accounting Office Report, NAVY SHIPS: Seawolf Cost Increases and Schedule Delays Continue. GAO/NSIAD-94-201BR. 30 June 1994.

United States General Accounting Office Report, DEFENSE INVENTORY: Changes in DOD's Inventory, 1989-93. GAO/NSIAD-94-235. 17 August 1994.

United States General Accounting Office Report. DEFENSE SUPPLY: Acquisition Lead time Requirements Can Be Significantly Reduced. GAO/NSIAD-95-2. 20 December 1994.

United States General Accounting Office Report. DEFENSE INVENTORY: Opportunities to Reduce Warehouse Space. GAO/NSIAD-95-64. 24 May 1995.

United States General Accounting Office Report. DEFENSE INVENTORY: Extent of Diminishing Manufacturing Sources Problems Still Unknown. GAO/NSIAD-95-85. 21 April 1995.

United States General Accounting Office Report. INVENTORY MANAGEMENT: DOD Can Build on Progress in Using Best Practices to Achieve Substantial Savings. GAO/NSIAD-95-142. 4 August 1995.

United States General Accounting Office Report. ADDRESSING THE DEFICIT: Updating Budgetary Implications of Selected GAO Work. GAO/OCG-96-5. 28 June 1996.

United States General Accounting Office Report. INVENTORY MANAGEMENT: Adopting Best Practices Could Enhance Navy Effects to Achieve Efficiencies and Savings. GAO/NSIAD-96-156. 12 July 1996.

United States General Accounting Office Report. New Attack Submarine Program Status. GAO/NSIAD-97-25. 3 December 1996.

United States General Accounting Office Report. DEFENSE INVENTORY: Spare and Repair Parts Inventory Costs Can Be Reduced. GAO/NSIAD-97-47. January 1997.

Walls. Gregory. "Program Budget and Execution." *Principles of Program Management II (MN 3222) Course Curriculum*. Naval Postgraduate School. Monterey, CA. May 1997.

Webster's II New Riverside University Dictionary. Riverside Publishing Company. Boston. 1984.

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